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This Draft EIS addresses proposed wastewater facilities for the Mammoth Cave Area cities of Horse Cave, Cave City, Park City and Munfordville, Kentucky and the Mammoth Cave National Park. Eight wastewater management alternatives have been evaluated with particular attention to the sensitivity of the cave environment to wastewater discharges, the resource value and importance of the caves, the complexity of the area's subsurface hydrology and the financial impacts of the alternatives on the communities.

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Environmental Impact Statement

Draft

Mammoth Cave Area, Kentucky

Environmental Inventory Technical Reference Document

Vol. I

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MAMMOTH CAVE AREA, KENTUCKY

201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

ENVIRONMENTAL INVENTORY

TECHNICAL REFERENCE DOCUMENT

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IV
ATLANTA, GEORGIA 30365

i.a

ENVIRONMENTAL IMPACT STATEMENT
ENVIRONMENTAL INVENTORY TECHNICAL REFERENCE DOCUMENT
MAMMOTH CAVE AREA, KENTUCKY
201 FACILITIES PLAN

TABLE OF CONTENTS

		Page
PART A.	DESCRIPTION OF THE STUDY AREA	I - 1
PART B.	NATURAL ENVIRONMENT	I - 2
	1. CLIMATE	I - 2
	2. AIR QUALITY	I - 2
	3. ODOR	I - 3
	4. NOISE	I - 3
	5. TOPOGRAPHY	I - 4
	6. GEOLOGY	I - 4
	7. SOILS	I - 14
	8. SURFACE WATER RESOURCES	I - 20
	9. SUBSURFACE WATER RESOURCES	I - 29
	10. AQUATIC ECOLOGY	I - 73
	11. CAVE ECOLOGY	I - 84
	12. TERRESTRIAL ECOLOGY	I - 100
	13. RARE AND ENDANGERED SPECIES	I - 104
PART C.	MAN-MADE ENVIRONMENT	I - 108
	1. POPULATION CHARACTERISTICS	I - 108
	2. LAND USE	I - 111
	3. ECONOMIC CONDITIONS	I - 115
	4. CULTURAL RESOURCES	I - 123
	5. RECREATIONAL RESOURCES	I - 127
	6. TRANSPORTATION	I - 129
	7. RESOURCE USE	I - 130
	8. WASTEWATER TREATMENT FACILITIES AND PROGRAMS	I - 132
	9. WATER SUPPLY	I - 157
	10. COMMUNITY SERVICES AND FACILITIES	I - 162
	11. OTHER PROJECTS AND PROGRAMS	I - 171
APPENDIX I		IA-1

LIST OF TABLES

Table		Page
I-1	Average Temperature and Precipitation Data from Bowling Green, Kentucky Weather Station	I - 3
I-2	Physical Description of Soil Associations and Soil Series	I - 15
I-3	Criteria for Establishing Soil Suitabilities for On-Lot Disposal, Soil Conservation Service, U.S. Dept. of Agriculture	I - 19
I-4	Soil Factors Required for Spray Irrigation and Overland Flow	I - 21
I-5	Soil Factors Which May Limit the Use of Septic Tanks, Spray Irrigation and Overland Flow Within Soil Associations in the Study Area	I - 22
I-6	Water Quality Data for Green River at Munfordville	I - 26
I-7	Springs Along the Green River	I - 33
I-8	Basin Discharge Data	I - 37
I-9	Runoff and Evapo-Transpiration Losses	I - 38
I-10	Comparison of Means of Chemical Analyses of Effluent-Bearing Springs with Those of Other Relevant Sites	I - 41
I-11	Summary of Chemical Analyses (Mean, Maximum and Minimum) at Relevant Sites	I - 42
I-12	EPA Criteria for Selected Water Quality Parameters for Use Classifications of Aquatic Life, Drinking Waters and Bathing Waters	I - 53
I-13	Summary Notes on Results of Grab Samples at each Sampling Site during Moderate and Low Flow Sampling Conditions	I - 55
I-14	Summary of Field Data on Sample Sites	I - 79
I-15	Sample Values, Means (X), Standard Deviations (s x 100/$\bar{x}$) for the Number of Individuals (N), Number of Species (S) Diversity ($\bar{d}$) and Equitability (e) sampled for the Mammoth Cave Area, Environmental Impact Statement	I - 82
I-16	Typical Environmental Parameters for Caves	I - 86
I-17	Kinds of Disturbance	I - 90
I-18	Externally Derived Impacts on Caves	I - 92

LIST OF TABLES (Cont'd.)

Table		Page
I-19	Wet Weights (g), Analysis Results (mg/l) and Concentrations (ug/g wet weight) of Nickel, Zinc, Chromium and Copper in Cave Crayfish Tissue Samples	I - 97
I-20	Survey Results on Current Farm Acreage Commitments to Assorted Crops	I - 101
I-21	Dominant Tree Species for Four Plant Associations within the Study Area	I - 102
I-22	Rare and Endangered Species of the Study Area	I - 106
I-23	Kentucky Program Development Office Population Projections with 1975 and 1977 Population Estimates	I - 109
I-24	Population Trends of Counties and Incorporated Cities 1940-1970	I - 110
I-25	Population Projections for Municipal Population Centers	I - 112
I-26	Mammoth Cave National Park Projected Visitation (Visitors/Day)	I - 113
I-27	Employment Data by County 1971-1976	I - 116
I-28	Employment by Industry, by Place of Work: 1975 and 1976	I - 117
I-29	Unemployment Trends, 1965-1975	I - 119
I-30	Total Personal and Per Capita Income	I - 120
I-31	Median Family Income	I - 121
I-32	Labor Force Characteristics	I - 122
I-33	Retail Business Trends (Number of Establishments)	I - 124
I-34	Retail Business Trends (Sales)	I - 125
I-35	Existing and Planned Recreational Areas within the Study Area	I - 128
I-36	Resource Use by County within the Study Area	I - 131
I-37	Percent of County Land Area Used as Commercial Forested Land (1966)	I - 133
I-38	Annual Total Oil Production in the Study Area (x 1000 gallons)	I - 134
I-39	Horse Cave Wastewater Treatment Plant Performance Data	I - 136

LIST OF TABLES (Cont'd.)

Table		Page
I-40	Munfordville Wastewater Treatment Plant Performance Data	I - 138
I-41	Cave City Wastewater Treatment Plant NPDES Permit Conditions	I - 140
I-42	Mammoth Cave National Park Wastewater Treatment Plant Performance Data	I - 142
I-43	Great Onyx Job Corps Center Wastewater Treatment Plant Performance Data	I - 144
I-44	Small Wastewater Treatment Plants	I - 145
I-45	Ken Dec Water Use June 1976 - July 1977 .	I - 147
I-46	Wastewater Characteristics Industrial Discharge of Ken-Dec, Inc.	I - 148
I-47	Expected Maximum Concentrations (mg/l) of Metals in Pretreated Wastewaters from Ken Dec, Inc.	I - 149
I-48	1974-1977 Water Consumption Records for the Combined Operations of Hart County Creameries and Wheyco, Inc.	I - 149
I-49	Hart County Creameries' Wastewater Characteristics as Reported by the Kentucky Division of Water Quality	I - 151
I-50	Summary of Outstanding Bond Issues June 30, 1977	I - 153
I-51	Wastewater Flow Projections for Study Area Population Centers	I - 155
I-52	Sulfate Contents in Parker River Cave System	I - 156
I-53	Public Water Supplies in the Study Area	I - 159
I-54	Municipal and National Park Water Systems	I - 160
I-55	Water Consumption Projections for Municipal Population Centers	I - 163
I-56	Water Consumption Projections for Mammoth Cave National Park for the Peak Month of the Tourist Season	I - 164
I-57	Health Care Manpower	I - 165
I-58	Education Levels Median School Years Completed	I - 167
I-59	School District Enrollments	I - 168
I-60	Local Property Tax Rate Per $100 of Assessed Valuation, 1975	I - 169
I-61	Utility Companies in the Study Area	I - 170

LIST OF FIGURES

Figure		Following Page
I-1	Regional Location Map	I - 1
I-2	EIS Study Area	I - 1
I-3	Geologic Cross-section	I - 5
I-4	Springs Along the Green River	I - 8
I-5	Frequency-Depth Relationship of Sinkholes	I - 9
I-6	Cave System Locations	I - 10
I-7	Soil Associations	I - 14
I-8	Soil Suitability for Spray Irrigation	I - 21
I-9	Central Kentucky Karst Hydrologic Arrangement	I - 29
I-10	Discharge Distribution of Green River Springs	I - 32
I-11	Groundwater Basins and Subsurface Flow	I - 34
I-12	Sampling Station Locations	I - 44
I-13	Sampling Sites in Parker Cave	I - 44
I-14	Dissolved Oxygen Concentrations in the Turnhole Spring Basin	I - 60
I-15	Ammonia Concentrations in the Turnhole Spring Basin	I - 61
I-16	NO_3-N Concentrations in the Turnhole Spring Basin	I - 61
I-17	Total Dissolved Solids Concentrations in the Turnhole Basin	I - 61
I-18	Chloride Concentrations in the Turnhole Spring Basin	I - 62
I-19	Sulfate Concentrations in the Turnhole Spring Basin	I - 62
I-20	Iron Concentrations in the Turnhole Spring Basin	I - 62
I-21	Total Zinc Concentrations in the Turnhole Spring Basin	I - 63
I-22	Fecal Coliform Densities at Turnhole Basin Sampling Sites	I - 63
I-23	Dissolved Oxygen Concentrations in the Hidden River Basin	I - 64

LIST OF FIGURES (Cont'd.)

Figure		Following Page
I-24	BOD_5 Concentrations in Hidden River Basin	I - 64
I-25	Ammonia Nitrogen Concentrations in Hidden River Basin	I - 65
I-26	Nitrate Nitrogen Concentrations in the Hidden River Basin	I - 65
I-27	Total Dissolved Solids Concentrations in Hidden River Basin	I - 65
I-28	Chloride Concentrations in Hidden River Basin	I - 65
I-29	Sulfate Concentrations in Hidden River Basin	I - 65
I-30	Total Chromium Concentrations in Hidden River Basin	I - 65
I-31	Nickel Concentrations in Hidden River Basin	I - 66
I-32	Total Copper Concentrations in Hidden River Basin	I - 66
I-33	Total Zinc Concentrations in Hidden River Basin	I - 66
I-34	Fecal Coliform Densities in Hidden River Basin	I - 66
I-35	Dissolved Oxygen Concentrations in the Final Basin Discharges to the Green River	I - 67
I-36	BOD_5 Concentrations in the Final Basin Discharges to the Green River	I - 67
I-37	Fecal Coliform Densities in the Final Basin Discharges to the Green River	I - 67
I-38	Total Nickel Concentrations in the Final Basin Discharges to the Green River	I - 67
I-39	Total Copper Concentrations in the Final Basin Discharges to the Green River	I - 67
I-40	Total Zinc Concentrations in the Final Basin Discharges to the Green River	I - 67
I-41	Total Chromium Concentrations in the Final Basin Discharges to the Green River	I - 67
I-42	Base Flow Dissolved Oxygen Concentrations at Hick Spring and Gorin Mill Spring	I - 68
I-43	Dissolved Oxygen Concentrations during Sept.-Nov. 1978 at Apple Grove Drainage (#4)	I - 68

LIST OF FIGURES (Cont'd.)

Figure		Following Page
I-44	Dissolved Oxygen Concentrations during Sept.-Nov. 1978 at Mill Hole (#14)	I - 68
I-45	Dissolved Oxygen Concentrations during Sept.-Nov. 1978 at South Branch Hidden River (#17)	I - 68
I-46	Dissolved Oxygen Concentrations during Sept.-Nov. 1978 at East Branch Hidden River Cave (#18)	I - 68
I-47	Dissolved Oxygen Concentrations during Sept.-Nov. 1978 at Blue Spring Branch (#19)	I - 68
I-48	Dissolved Oxygen Concentrations during Sept.-Nov. 1978 at L&N Cave (#20)	I - 68
I-49	Total Kjeldahl, Ammonia and Nitrate Nitrogen Concentrations during Sept.-Nov. 1978 at South Branch Hidden River Cave	I - 69
I-50	Total Kjeldahl, Ammonia and Nitrate Nitrogen Concentration during Sept.-Nov. 1978 at East Branch Hidden River Cave	I - 69
I-51	Total Kjeldahl, Ammonia and Nitrate Nitrogen Concentration during Sept.-Nov. 1978 at Apple Grove Drainage	I - 69
I-52	Total Kjeldahl, Ammonia, and Nitrate Nitrogen Concentration during Sept.-Nov. 1978 at Blue Spring Branch	I - 69
I-53	Total Kjeldahl, Ammonia and Nitrate Nitrogen Concentration during Sept.-Nov. 1978 at Mill Hole	I - 69
I-54	Total Kjeldahl, Ammonia and Nitrate Nitrogen Concentration during Sept.-Nov. 1978 at L&N Cave	I - 69
I-55	Total Chromium Concentrations during Sept.-Nov. 1978 at Horse Cave Trattment Plant effluent and South Branch Hidden River	I - 69
I-56	Total Copper Concentrations during Sept.-Nov. 1978 at Horse Cave Treatment Plant Effluent and South Branch Hidden River	I - 69
I-57	Total Nickel Concentrations during Sept.-Nov. 1978 at Horse Cave Treatment Plant Effluent and South Branch Hidden River	I - 69
I-58	Total Zinc Concentrations during Sept.-Nov. 1978 at Horse Cave Treatment Plant Effluent and South Branch Hidden Cave	I - 69

LIST OF FIGURES (Cont'd.)

Figure		Following Page
I-59	Conductivity Levels during Sept.-Nov. 1978 at L&N Cave	I - 69
I-60	Conductivity Levels during Sept.-Nov. 1978 at Blue Spring Branch	I - 70
I-61	Conductivity Levels during Sept.-Nov. 1978 at Apple Grove Drainage	I - 70
I-62	Conductivity Levels during Sept.-Nov. 1978 at South Branch Hidden River	I - 70
I-63	Conductivity Levels during Sept.-Nov. 1978 at East Branch Hidden River	I - 70
I-64	Conductivity Levels during Sept.-Nov. 1978 at Mill Hole	I - 70
I-65	A Simplified Compartmentalization of a Woodland Stream Ecosystem Structure	I - 74
I-66	Simplified Compartmentalization of Energy Flow Between Four Ecosystems	I - 84
I-67	Interrelations of Kinds of Disturbances Caused by Improper Land Use Practices Resulting in the Simplification of the Cave Community	I - 90
I-68	Generalized Existing and Future Land Use	I - 114
I-69	Archeological, Historical and Recreational Sites	I - 125
I-70	Natural Resources	I - 131
I-71	Schematic of Horse Cave Wastewater Treatment Plant	I - 134
I-72	Wastewater Treatment Facilities	I - 135
I-73	Schematic Diagram of Munfordville Wastewater Treatment Plant	I - 137
I-74	Schematic Diagram of Cave City Wastewater Treatment Plant	I - 139
I-75	Schematic Diagram of Mammoth Cave National Park Wastewater Treatment Plant	I - 141
I-76	1977 Daily Average Water Consumption by Month for Hart County Creameries and Whayco	I - 149
I-77	Contaminated Well Sites	I - 152

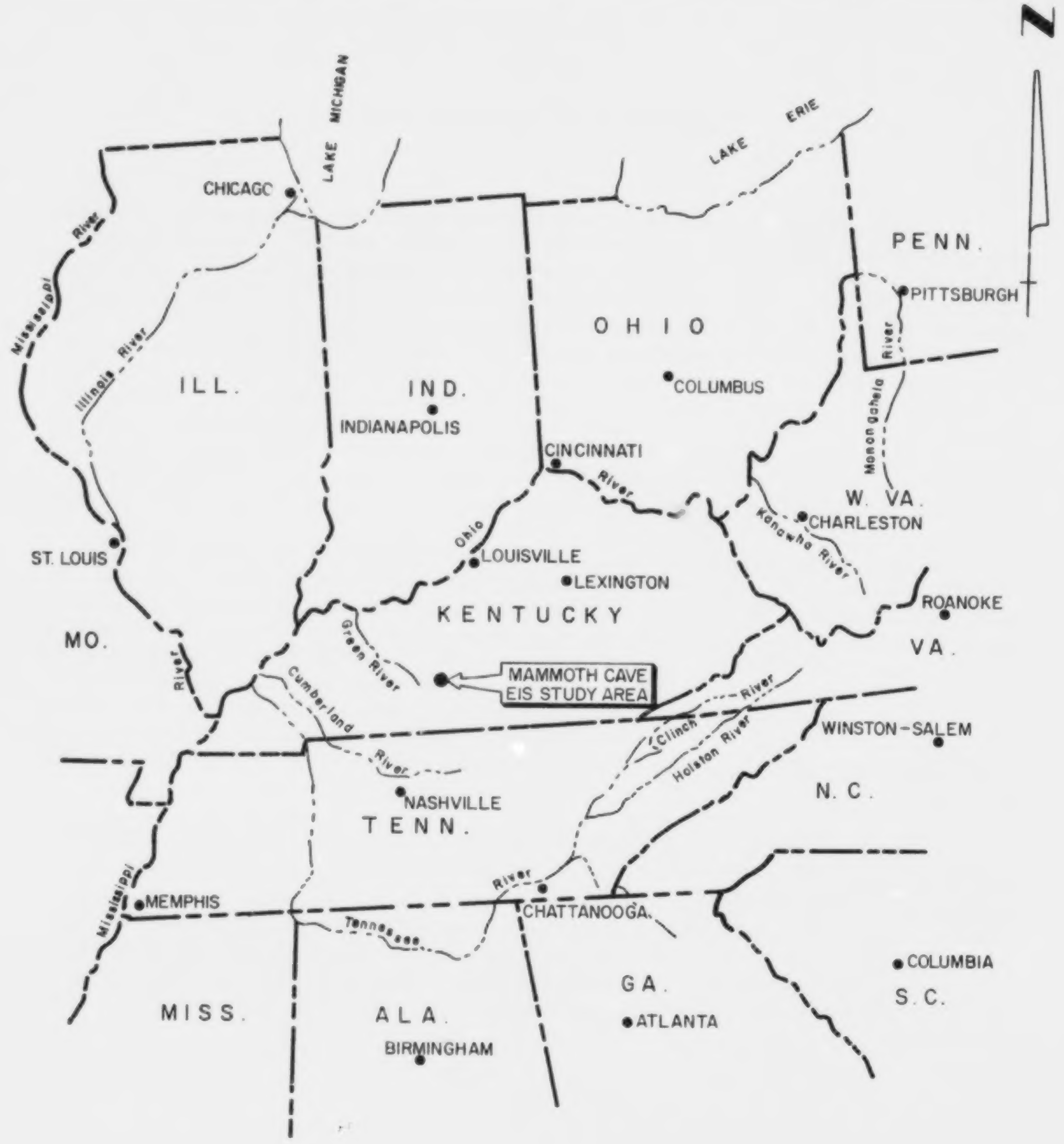
PART A

DESCRIPTION OF THE STUDY AREA

The study area is located in the Central Kentucky Karst, south central Kentucky, about 100 miles southwest of Louisville, Kentucky and 100 miles northeast of Nashville, Tennessee traveling on interstate 65 (Figure I-1). The 201 wastewater facilities planning area, depicted on Figure I-2, begins north of Munfordville, runs south to a point below Park City and then west to the Green River. The irregularly shaped 201 planning area is partially situated in Barren, Hart and Edmonson Counties, and includes the municipalities of Munfordville, Horse Cave, Cave City and Park City as well as portions of Mammoth Cave National Park. A very small portion of Warren County is also included in the 201 planning area. However, since this area is so small and sparsely populated, it is not expected to significantly impact wastewater treatment facilities planning, and is therefore not included in this inventory.

The 201 planning area is delineated by the Kentucky Division of Water Quality and the U.S. Environmental Protection Agency with input from the localities involved. This area defines the boundaries for the study of providing wastewater treatment facilities and not necessarily the area of environmental impact. The Environmental Impact Statement (EIS) study area includes the 201 area as well as those surrounding areas which may be impacted by, or have a significant impact on, 201 Facilities Planning, nearly the entire area shown in Figure I-2. It is this area that is the subject of the Environmental Technical Reference Document. In this report the "study area" refers to the EIS study area (Figure I-2).

As is characteristic of the Central Kentucky Karst, the study terrain is gently rolling and pitted with sinkholes while the subsurface contains a complex structure of limestone caves and mostly free flowing groundwaters. However, there is also a small "diffuse" component of the groundwater. The area's unique geological features are of national interest and provide the area with a strong tourist attraction. Other than the tourist industry at the National Park and bordering municipalities, the area is primarily rural/agricultural.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PENN.
PITTSBURGH
OHIO
COLUMBUS
ILL.
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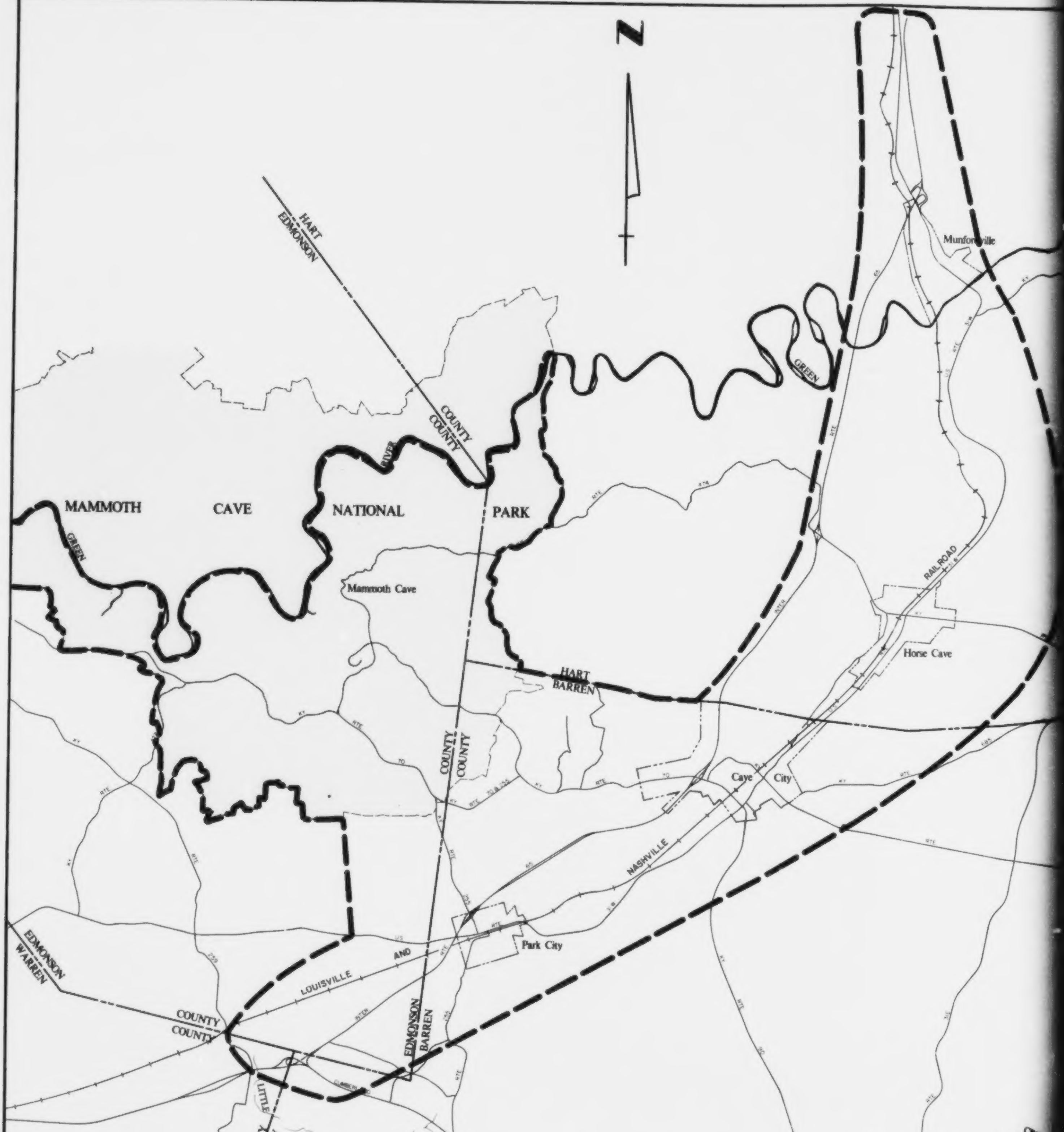
INDIANAPOLIS
Mississippi River
Illinois River
CINCINNATI
Ohio River
Monongahela River
River
W. VA.
CHARLESTON
Kanawha River
ST. LOUIS
LOUISVILLE
LEXINGTON
KENTUCKY
ROANOKE
VA.
MO.
River
Green River
MAMMOTH CAVE EIS STUDY AREA
Cumberland River
Clinch River
Holston River
WINSTON-SALEM
N. C.
NASHVILLE
TENN.
Mississippi
MEMPHIS
River
CHATTANOOGA
Tennessee
COLUMBIA
S. C.
GA.
MISS.
ALA.
ATLANTA
BIRMINGHAM

FIGURE I-1

MAMMOTH CAVE AREA
201 FACILITIES PLAN
ENVIRONMENTAL IMPACT STATEMENT

REGIONAL LOCATION MAP

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia


N
HART
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GREEN
RIVER
MAMMOTH
CAVE
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PARK
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RAILROAD
Horse Cave
HART
BARREN
COUNTY
COUNTY
Cave
City
NASHVILLE
Park City
EDMONSON
WARREN
LOUISVILLE
AND
COUNTY
COUNTY
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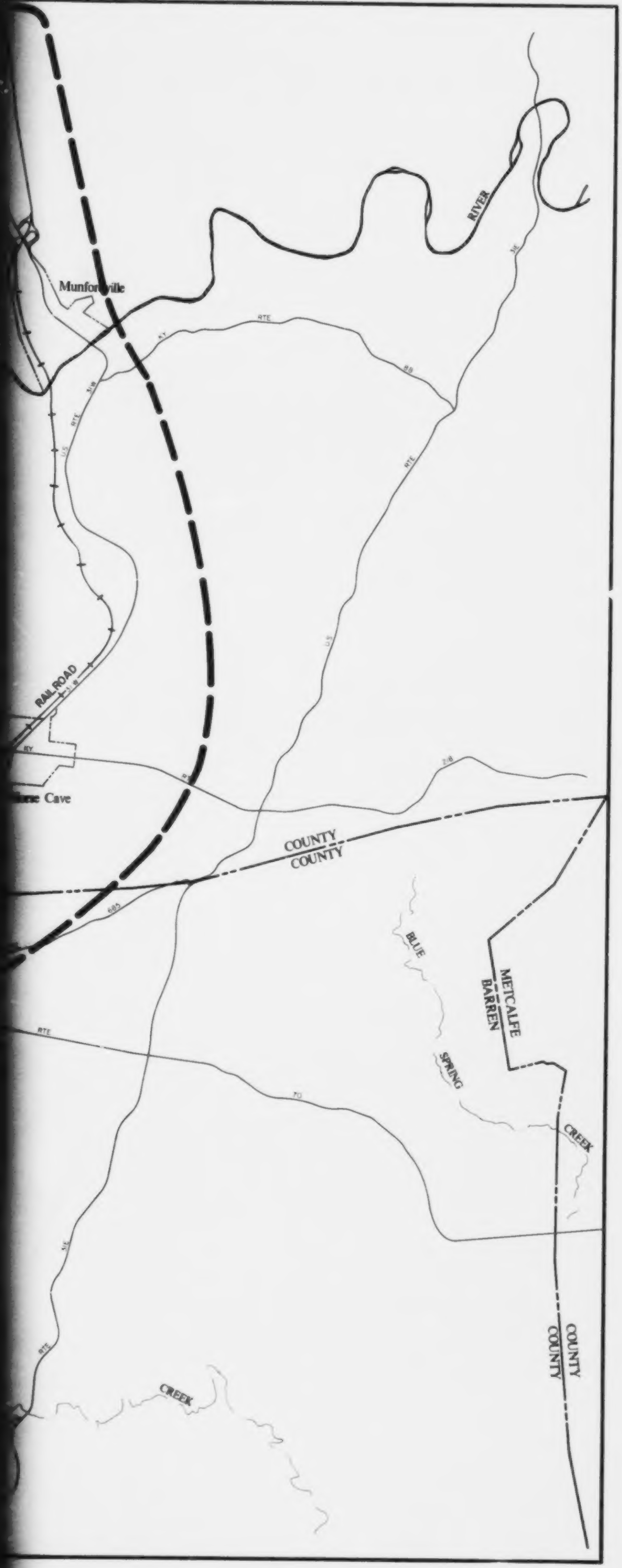
A

I-1-b


RIVER
Munfordville
RTE
KY
88
31E
U.S.
RAILROAD
Cave
218
COUNTY
COUNTY
685
BLUE
SPRING
CREEK
METCALFE
BARREN
TO
COUNTY
COUNTY
CREEK

B

LEGEND

▨ MAMMOTH CAVE NATIONAL PARK

▬ ▬ 201 FACILITIES PLANNING LIMITS

FIGURE I-2

MAMMOTH CAVE AREA
201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

EIS STUDY AREA

12,000 6000 0 12,000 24,000
Scale In Feet

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia

PART B

NATURAL ENVIRONMENT

1. CLIMATE

The study area has a variable continental climate with wide extremes in both temperature and precipitation. Bowling Green, which lies about 30 miles southwest of Mammoth Cave, has the closest weather stations with complete records. The average annual temperature is about 59°F. In the last 100 years, the minimum recorded temperature was -21°F and the maximum was 113°F. Precipitation is well distributed throughout the year and averages about 49 inches per year. Droughts have occurred, but they are short in duration. The driest month, October, averages over 2 inches of rain throughout the month. The wettest month, January, has an average rainfall of over 5 inches. Average monthly temperatures and average monthly rainfall data for the period 1931-1955 for Bowling Green, Kentucky are presented in Table I-1.

The lowest average wind speeds of any station in the United States have been measured at Bowling Green, Kentucky. The average daily wind speed for the entire year is between 6 and 7 m.p.h. The strongest wind gust ever recorded was 67 m.p.h. The prevailing wind direction is from south to southwest. During the fall, some areas have winds with a prevailing northerly direction.

The number of tornadoes occurring in Kentucky increases as one goes west in Kentucky. Between 1950 and 1977 there have been 6 tornadoes in Barren County, 1 in Edmonson County, 8 in Warren County, and 3 in Hart County.

References:

Anderson, O.K. 1959. Climate of Kentucky. U.S. Department of Commerce Weather Bureau

Cockrill, W. Willard. 1975. A BRADD Weather Report. Weather and Climate of the Barren River Area Development District. 29 pages.

Personal communication, Ken Smith BRADD, June 5, 1978.

2. AIR QUALITY

Because the area is primarily rural, severe air pollution problems do not occur. The main source of air pollution is the exhaust emissions from vehicles used by local residents and tourists visiting the Mammoth Cave National Park. The occasional burning of trash and debris results in minor, short time, local pollution.

References:

Mammoth Cave environmental assessment. Alternative relocation sites. November, 1976. U.S. Department of the Interior, page 2-9.

Personal communication, Ken Smith BRADD, June 5, 1978.

TABLE I-1

AVERAGE TEMPERATURE AND PRECIPITATION DATA FROM BOWLING GREEN, KENTUCKY WEATHER STATION

Month	Average Temperature	Average Precipitation
January	38.7	5.82
February	40.5	4.03
March	48.5	5.63
April	58.3	4.04
May	67.3	3.81
June	76.4	3.94
July	79.4	4.27
August	78.0	3.71
September	71.6	3.19
October	60.2	2.34
November	47.3	3.47
December	39.2	4.42
Annual	58.8	

Source: Anderson, OK. 1959. Climate of Kentucky. U.S. Department of Commerce Weather Bureau.

3. ODOR

No major odor producers have been identified within the boundaries of the study area. The sewage treatment plants, Ken-Dec metal plating plant and local creamery wastes are potential sources of odor.

Odor problems do occur seasonally in Horse Cave, Kentucky. Sewage effluent from the Horse Cave wastewater treatment plant, which discharges to a sink hole, has been traced to the Hidden River Cave System. Lack of oxygen and presence of sewage effluent at the mouth of Hidden River Cave cause a noxious odor in downtown Horse Cave, especially in summer months. This problem is not new to Horse Cave. Hidden River Cave had been operated as a tourist attraction from 1916 until 1944, but by then, in spite of law suits and countersuits, the cave was forced to close because of malodorous and aesthetic problems caused by fecal waste and, beginning in 1944, whey from a local creamery.

Reference: Quinlan, James. Phase I Management Report No. 12, page 6.

4. NOISE

Overall, the study area is undeveloped and relatively quiet. The developed areas of Horse Cave, Cave City, and Park City are primarily residential with some commercial areas and are consequently not noisy areas. The greatest noise centers in Mammoth Cave National Park are around the visitor's center, the tourist caves, the parking lot and the small residential area within the park.

The major noise generators are the highways and railroads listed and described below:

Noise Generator	Description
U. S. Route 31W	Route 31W passes through Park City, Cave City, Horse Cave, and Munfordville. It is the only major route that passes through each of these towns.
Interstate 65	Interstate 65 runs almost parallel to Route 31W. High speed travel and truck traffic is common on this major highway. Service stations, restaurants, and motels cluster around each of the interchanges leading to Mammoth Cave National Park, Park City, Cave City and Horse Cave.
Route 70	Route 70 traverses the study area from east to west. It passes through Cave City and is a major access route into Mammoth Cave National Park.
Railroad Corridor	Running almost parallel to Route 31W, the Louisville and Nashville Railroad passes through the study area from southwest to north-northeast. It passes through Park City, Cave City, Horse Cave and Munfordville. A railroad official described the railroad as heavily used.

5. TOPOGRAPHY

The study area is within the physiographic region known as the Mississippian Plateau. The topography is referred to as karst topography. The terrain is characterized by numerous sinkholes and other features, primarily vertical shafts and caves, formed by subsurface solution of limestone. An escarpment runs through the study area from the southwest corner to the northeast corner. The sinkholes are commonly found to the southeast of this escarpment. Elevations range from 450 feet above sea level along the Green River in the western portion of the study area to nearly 1000 feet above sea level in eastern Hart County.

Steep slopes (>25%) are commonly found along the banks of the Green River and the escarpment. Because of steep sloping river banks, the Green River does not have wide flood plains. Some flooding of caves occurs during periods of high flow.

6. GEOLOGY

General Geology of the Area

Geologic Setting

The study area occupies a considerable portion of the area widely known as the "Central Kentucky Karst". The Central Kentucky Karst is an area in the center of the Mississippian Plateau of central and western Kentucky. It consists of the Pennyroyal Plateau to the south and east (which is further subdivided into the Sinkhole Plain and the Glasgow Upland), Chester Cuesta (sometimes called the Mammoth Cave Plateau), and the Western Coal Field. The Pennyroyal Plateau and the Chester Cuesta are separated by the 60-meter high Chester Escarpment (shown as the Dripping Springs Escarpment on older maps). The Central Kentucky Karst is an integral part of and is continuous with, the karsted belt of the Mississippian carbonate rocks that extend north into Indiana, south into Tennessee, and west to the Cumberland River. This karsted belt lies along the entire edge of the Western Kentucky Coal Field, a part of the great Illinois Basin. The Chester Cuesta is physiographically and stratigraphically correlative with the Crawford Upland of Indiana and the Sinkhole Plain is equally correlative with the Mitchell Plain. The setting is summarized by White et. al. (1970), Quinlan (1970), Miotke and Palmer (1972) and Miotke (1973-a, b).

The southern and eastern border of the karst is underlain by shale, calcareous siltstone, clayey dolomite, and limestone of the Fort Payne formation. This portion of the area has a topography of elongate, dissected rolling hills with about 50 meters of local relief. Nearly all of the sinking streams and swallow holes on the Glasgow Upland are developed in the overlying relatively more soluble Salem and Warsaw limestones.

The lower half of the overlying St. Louis formation is calcareous and dolomitic, but relatively insoluble and impervious: it is near the middle of this formation that the boundary between the Sinkhole Plain and the Glasgow Upland is drawn because of the abrupt contrast in the number of sinkholes per unit area and because many surface streams go underground at about this stratigraphic horizon. The overlying 130 meters of relatively pure carbonate rocks are divided near the Ste. Genevieve-St. Louis contact by the Lost River Chert, a thin, persistant, and extremely resistant zone of bedded chert that caps part of the Sinkhole Plain and locally forms the Lost River escarpment. A minor unnamed chert bed near the Girkin-Ste. Genevieve contact also forms local topographic benches and retards deepening of the dry valleys.

Overlying the thick sequence of carbonate rocks is the Big Clifty sandstone and, locally, the Fraileys shale that forms the caprock of the Chester Escarpment, the ridges, and the knobs which are the remnants of former ridges. The resistance of this caprock to erosion is responsible not only for the development of karst landforms and vertical shafts but also the preservation of the long cave systems.

Much of the Haney limestone has been removed by interstratal karstification beneath the Hardinsburg sandstone but the geomorphic effects of the Mississippian limestones overlying the Big Clifty sandstone are of local rather than regional significance. Nevertheless, the Haney limestone is an important aquifer and in fact forms the water supply for Mammoth Cave National Park. The Hardinsburg sandstone forms a stripped structural surface on the dip slope of most of the Chester Cuesta.

The main features described above are summarized in a geologic cross-section constructed from U.S. Geologic Survey topographic and geologic maps (Fig. I-3). The section extends south to north from the Barren River in the south to Turnhole Spring on Green River in the north.

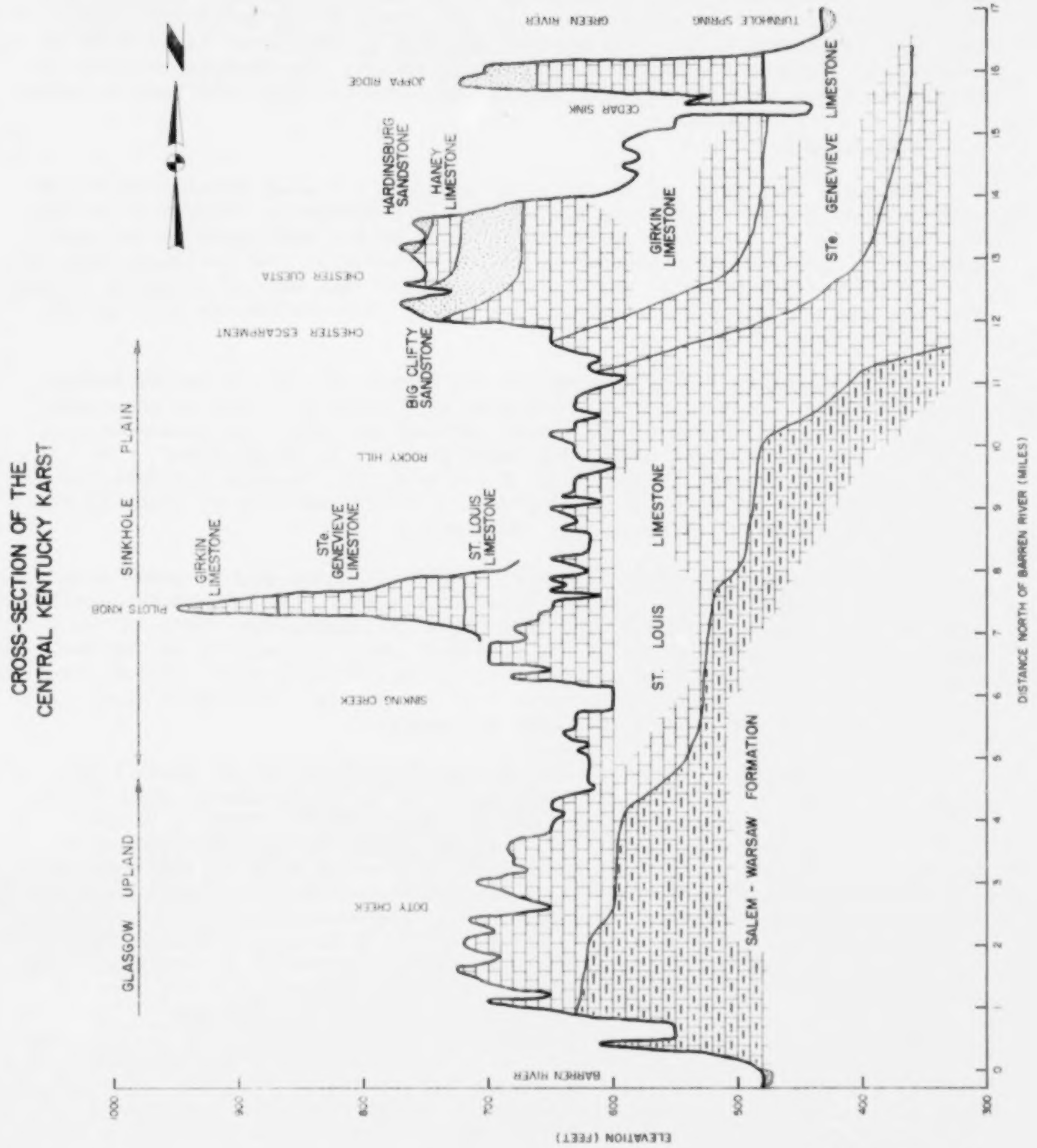

CROSS-SECTION OF THE
CENTRAL KENTUCKY KARST
GLASGOW UPLAND
SINKHOLE PLAIN
N
BARREN RIVER
DOTY CREEK
SINKING CREEK
PILOTS KNOB
ROCKY HILL
CHESTER ESCARPMENT
CHESTER CUESTA
JOPPA RIDGE
CEDAR SINK
GREEN RIVER
TURNHOLE SPRING
GIRKIN LIMESTONE
STe. GENEVIEVE LIMESTONE
ST. LOUIS LIMESTONE
BIG CLIFTY SANDSTONE
HARDINSBURG SANDSTONE
HANEY LIMESTONE
GIRKIN LIMESTONE
STe. GENEVIEVE LIMESTONE
ST. LOUIS LIMESTONE
SALEM - WARSAW FORMATION
ELEVATION (FEET)
1000
900
800
700
600
500
400
300
DISTANCE NORTH OF BARREN RIVER (MILES)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

FIGURE I - 3

The boundaries of the Central Kentucky Karst occur along natural hydrologic divides. The northern boundary is the Green River which is a master base level stream in the area. The southern boundary is the drainage divide between water that flows north onto the Sinkhole Plain and is part of the recharge of the carbonate aquifer there, and drainage that flows to the south into tributaries of the Barren River. The eastern boundary is also Green River where it crosses the Sinkhole Plain just east of Munfordville. The western boundary is the Barren River which flows north across the Sinkhole Plain near Bowling Green.

Stratigraphy

The rocks that crop out in the study area are of mainly Mississippian age with only the highest formation, the Caseyville formation of Pennsylvanian age. The limestones are clearly exposed in the walls of the many caves in the area, making very detailed stratigraphic examination possible. The following description for the limestone units is the largely unpublished work of Arthur N. Palmer who obtained his data from an examination of the rocks in Mammoth Cave and the Flint Ridge Cave System.

Girkin Formation (135 - 140 feet) - The Girkin consists of rather thick-bedded limestone units separated at intervals of roughly 20 feet by thin beds of shaly or sandy limestone. The impure beds can be easily distinguished by their crumbly, incompetent character, which produces recessed ledges. The Girkin is poorly exposed in the caves of the park. At the Historic Entrance of Mammoth Cave the Girkin thins locally to as little as 65 feet, owing to a reduction in thickness of nearly all its members.

Ste. Genevieve Limestone - The Ste. Genevieve can be distinguished from the Girkin Formation by the following characteristics: (1) Variations in rock type occur over more closely spaced intervals. (2) Except for those in the Bethel, beds of limestone pebbles are confined almost exclusively to the Ste. Genevieve. (3) Nodular chert is common at several stratigraphic horizons in the Ste. Genevieve. A vast majority of the cave passages in Mammoth Cave National Park are developed in the Ste. Genevieve.

St. Louis Limestone - Only the uppermost 50 feet of the St. Louis Limestone is exposed in the presently known parts of the Flint-Mammoth Cave System. This stratigraphic interval can be distinguished from the overlying Fredonia beds by several characteristics: (1) the dark brown color of most weathered surfaces, in contrast with the predominantly light gray color of the Fredonia; (2) thin interbeds of dark brown shale near the top of the St. Louis; and (3) abundant bedded chert in the lower beds of the exposed section. A 29-foot section of the St. Louis is exposed at the bottom of Mammoth Dome that shows the typical character of the non-cherty upper beds, but with an abnormally large thickness.

Structure

In the most general terms, the structural setting of the study area is that of a monocline with beds dipping gently to the northwest toward the Illinois Basin (or alternatively off the western flank of the Cincinnatti Arch). In detail, however, the structure is quite complex.

In the portion of the study area between Horse Cave and Munfordville, the structural dip is gentle, about 30 to 50 feet to the mile, the dip steepens to the south and west of the area. This is illustrated on the cross-section from Barren River to Green River which crosses south to north just west of Park City. Beneath the Sinkhole Plain the dip is gentle but there is a pronounced steepening at the edge of the escarpment. There is also a pronounced change in the dip just west of Park City. The dominantly east-west structural contours of the eastern portion of the area bend abruptly and the strike becomes mainly north-south. The structural configuration relates to the concentration of sinkholes found in this area and to the drainage divide between the underground flow line to the north to Turnhole Spring and the Graham Springs sub-basin where the drainage is mainly to the west.

Superimposed on the monoclinal flexture are a number of small anticlines and synclines trending generally but not always to the northwest. These small structural flextures have played an important role in guiding the initial pathways of underground drainage since the tops of these small anticlines are the first carbonate rock intersected by the Green River as it downcuts its channel. The intersection points are the first outlet for ground water from the carbonate aquifer and therefore the sites of paleospring mouths with attendant abandoned conduit system (Deike, 1967).

Numerous small faults occur in the study area. Most of these have not been mapped although a few appear on the U.S. Geological Survey Geologic Quadrangle maps. The Cub Run fault which crosses Green River in a north-south direction just east of the National Park boundary is some miles in length and has a throw of 40 feet. Other smaller faults occur but do not appear to be as extensive.

Although the rocks in the study area are strongly jointed, joints and fractures seem to be less important in determining the direction of ground water flow and in controlling the orientation of cave passages than are bedding plane partings. G. H. Deike mapped many joints, fracture systems, and lineaments visable on air photographs as part of his Ph.D. dissertation but found very weak correlations, if any, between these structural controls and the highly developed cave passages (Deike, 1967). Bedding plane partings appear to be the dominant source of secondary permeability in the Central Kentucky limestone aquifer.

Description of Karst Formations

Karst Valleys

Solutional karst valleys a half mile or more in width and several miles long, with sinkhole-pitted floors, extend in a dendritic pattern from the Green River into the Chester Cuesta. These valleys, which once contained perennial surface streams tributary to the Green, are consequent on the now-removed cap rock. With the breaching of the cap rock, drainage went underground, probably through the development of innumerable vertical shafts, and the valleys were abandoned as surface channels. However, the valleys have continued to widen and deepen by solutional activity beneath the soil mantle, by gullying, and by collapse of the walls. The solutional activity has transformed large parts of the once graded valleys into closed depressions, or valley sinkholes, some of which contain temporary ponds with clay-plug floors - for example, Doyel's Big Pond in Doyel Valley. Saddles extend from one wall to the other and separate sinkholes along the same valley. The floors of the valley sinkholes are as much as 150 feet below the saddle tops, which are not usually eroded much below the base of the cap rock. The main road into Mammoth Cave National

Park traverses Doyel Valley on a karst saddle. Doyel Valley, which separates Joppa Ridge from Mammoth Cave Ridge and Houchins and Eaton Valleys, which separate Mammoth Cave Ridge from Flint Ridge, are typical of this development. These are blind, dry, hanging valleys near their junctions with the Green River, owing to continued entrenchment of the Green after most of the valley drainage had been diverted underground. The mouth of Doyel Valley is 245 feet above the Green River.

Small streams that rise on the plateau flow over the edge of the sandstone caprock and sink at the limestone contact high on the flanks of the valleys. These swallow holes frequently lead to the tops of vertical shafts through which the surface runoff moves rapidly to base level. Some of the valleys contain short fragments of surface stream channel which are used during periods of high runoff. These likewise terminate in sinkholes in the bottom of the valley. The drainage in the section of the Cuesta near Mammoth Cave is completely deranged. No stream channels have uninterrupted profile to the river. Downstream from the Turnhole spring and on the north side of Green River, many of the channels do slope continuously down to Green River but the channels are usually dry; all drainage except flood runoff having been diverted underground.

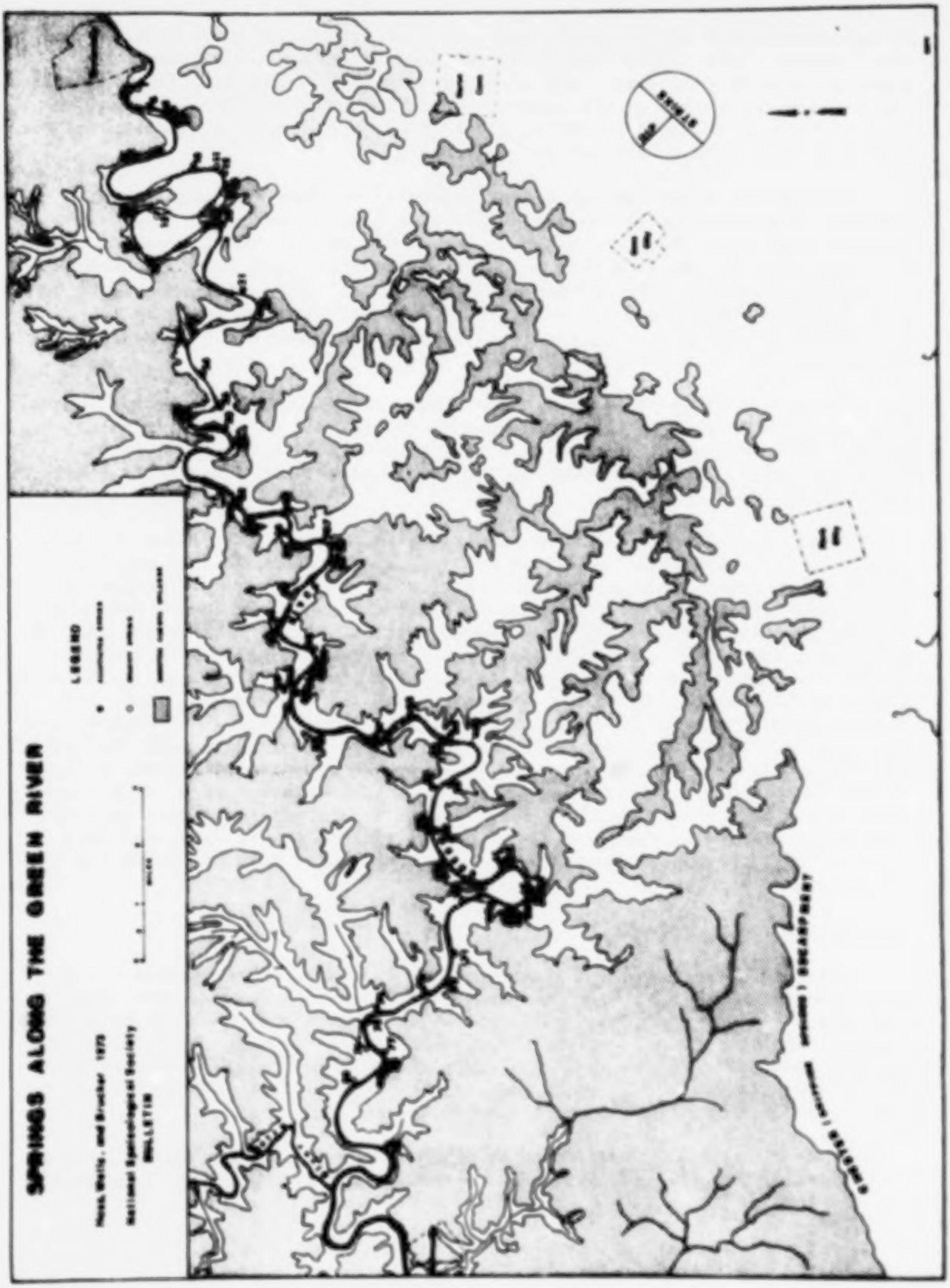
Steep-walled sinkholes occur on the margins of the karst valleys as well as on the valley bottoms. The sandstone caprock retards the retreat of the sinkwalls while solution continues to deepen them. The result is very steep walled sink with a rim of sandstone. Hunts Sink on Mammoth Cave Ridge is an example.

Sinks also form by the collapse of cavern roofs. Cedar Sink and Mill Hole are of this origin. Cedar Sink occurs near the bottom of Smith Valley and the walls are entirely in the limestone. Steep to overhanging cliffs form the walls of the sink from the rim at 540 feet elevation to nearly the level of Green River. The main underground drainage line from the Sinkhole Plain to the Turnhole Spring crosses the bottom of Cedar Sink. The stream can be observed as a flood spillover in a surface channel at high flow and crossing the bottom of Owl Cave, a short cave fragment in the north end of the sink, under all flow conditions. Mill Hole is likewise a karst fenster that gives access to the Turnhole Spring drainage that flows across its bottom in a surface channel.

The Chester escarpment itself is the result of both solution and collapse activity. As the cap rock to the southwest is removed, the limestones beneath it rapidly removed by solution, and the escarpment formed along the edge of the area still protected by cap rock. The escarpment is very sharp and distinct in the southwestern portion of the study area between Cave City and Park City. It is less distinct between Cave City and Horse Cave where the dip is less steep and is broken by re-entrant karst valleys. The distribution of karst valleys and the intervening ridges is shown on Figure I-4. The stippled areas represent the outcrop of the Big Clifty sandstone and the blank areas are the limestones. The numbers that appear along the course of Green River are observed springs to be discussed in a later section.

The Sinkhole Plain

The Sinkhole Plain consists of a rolling topography pocked with thousands of sinkholes. There are no surface streams and little evidence for channels


SPRINGS ALONG THE GREEN RIVER
Hess, Wells, and Brucker 1975
National Speleological Society
BULLETIN
LEGEND
ESCARPMENT

I-8-a

FIGURE I-4

or distinguishable valley development. The relief within short distances on the Sinkhole Plain varies from 30 to 100 feet with individual depressions usually 10 to 30 feet deep. All overland flow is diverted into the sinkholes. The rolling topography of the Sinkhole Plain is broken by the occasional knob that rises to elevations of 200 to 300 feet above the average elevation of the Sinkhole Plain (see cross-section in Figure I-3).

Most of the sinkholes are roughly circular in plan and roughly bowl-shaped. Some occur in linear groups and some have fragments of cave passage opening from them. Some are karst fensters with streams flowing across their bottoms. Most of the sinkholes are highly alluviated with unknown thicknesses of clastic sediment. The sediment layers are sufficiently impermeable to support sinkhole ponds which are widely used as stock watering ponds by the farmers. Pollen measurements suggest that the sinkhole ponds are ephemeral and can be expected to drain unexpectedly.

The distribution of sinkholes over the Plain is quite irregular. Some of the variation is probably of structural origin related to the out-crop pattern of the chert horizons in the lower Ste. Genevieve and St. Louis limestones. The chert serves as a local capping bed and localizes the groundwater infiltration.

Three origins have been proposed for the sinkholes: (i) solution sinks formed by the solutional removal of the limestone bedrock at some point of structural weakness such as the intersection of two joints which permits a localized infiltration of ground water (ii) collapse sinks formed when the underlying caves collapse (iii) roots of vertical shafts left behind when the escarpment retreated. Solution sinks would be expected to be more gentle sloped and bowl-shaped whereas the collapse sinks would be expected to be steep sided, perhaps with fragments of the collapsed cave still in evidence, and perhaps deeper in relation to their diameter. Although sinks of collapse origin are definitely known, many are mantled with soil which obscures the bedrock and the origin of most of the sinkholes cannot be assigned definitely to any of the three types. The frequency-depth relations measured by S. G. Wells as part of his M.S. thesis (Wells, 1971) (Figure I-5) shows that there is a continuous population of depths with very deep sinks much more rare than the shallow ones. However, there is no break in the curve to distinguish two populations.

Description of Local Caves

There is no published tabulation of the caves in the study area but their number must certainly be in excess of several hundred. Caves abound under the Sinkhole Plain, in the dissected margin of the Cuesta and under the main Cuesta ridges. Most of these caves are fragments of once-larger drainage conduits or are complexes of vertical shafts and their associated drains. The size scale of the caves ranges from tiny fragments a few tens of feet in length up to the Flint-Mammoth System, the longest cave in the world.

Other than Mammoth Cave which is exhibited by the National Park Service, the following private show caves are presently open to the public (alphabetical listing)

Crystal Onyx Cave	Prewitt Knob
Diamond Caverns	North of Park City

FREQUENCY - DEPTH RELATIONSHIPS OF SINKHOLES

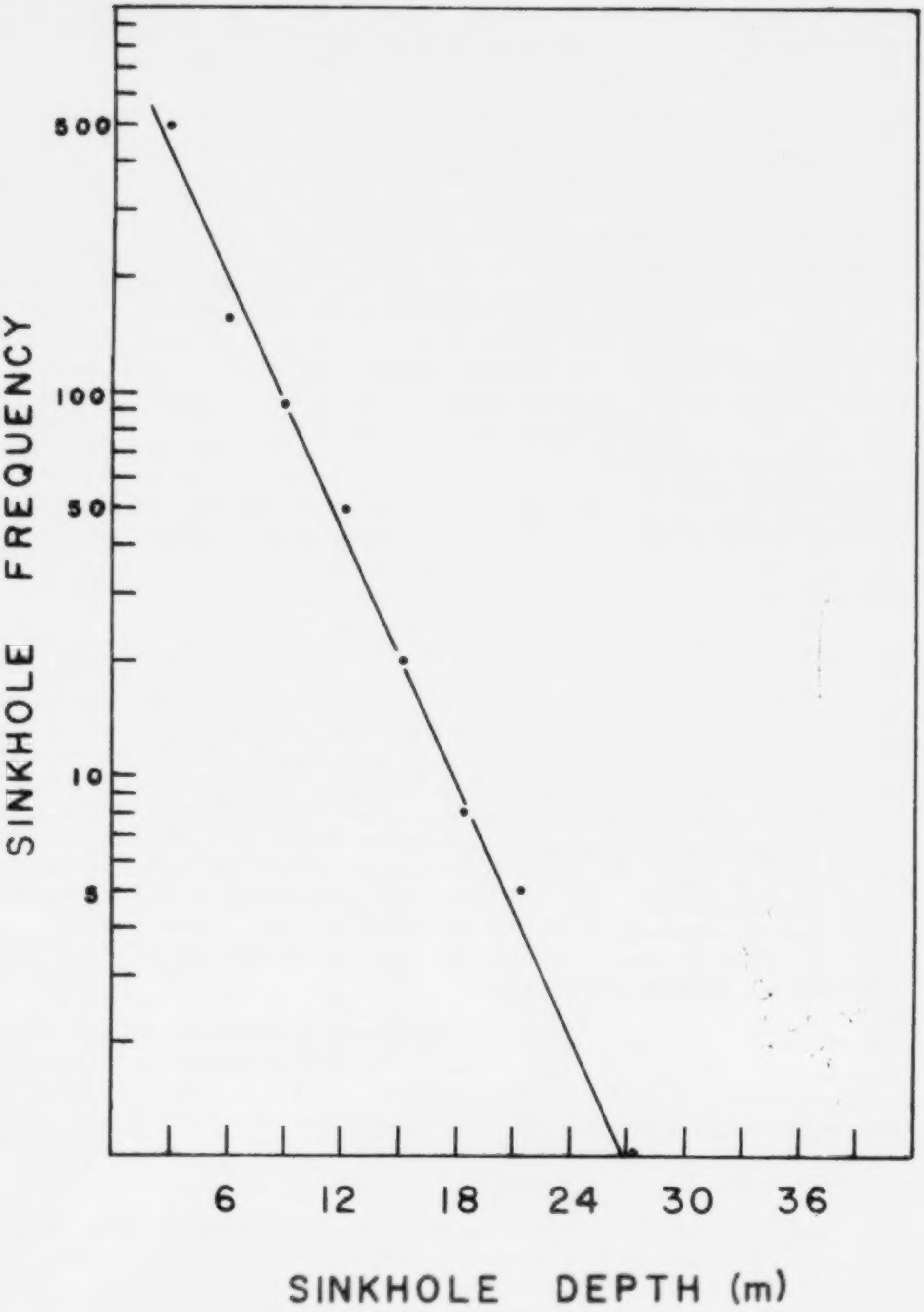


FIGURE I-5

Jesse James Cave Coach Cave	Park Mammoth Resort near Park City
Hundred Domes Cave Mammoth Onyx Cave	Near Horse Cave

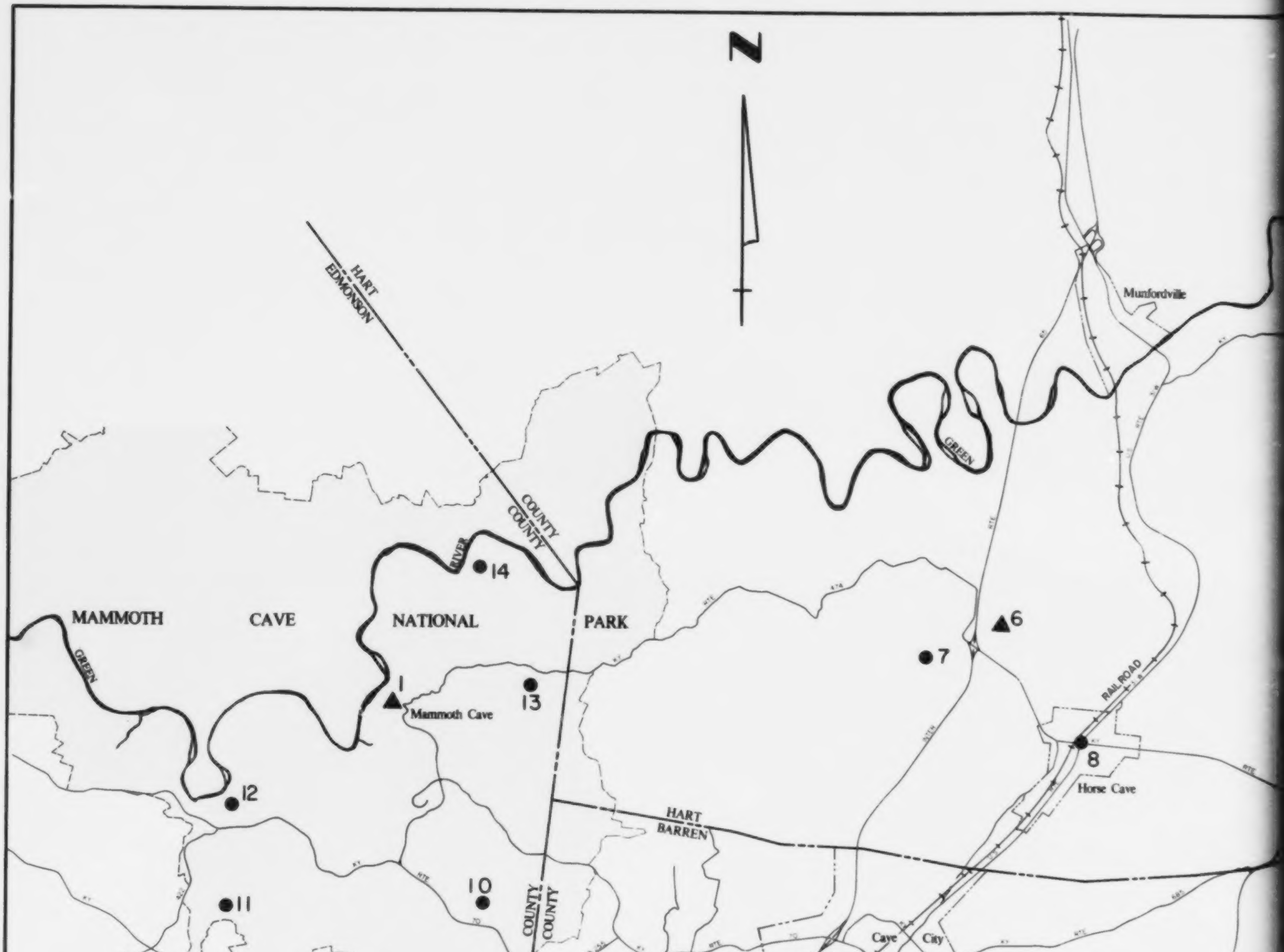
Many other caves in the area including Great Onyx Cave, Floyd Collins Crystal Cave and Hidden River Cave have been open as show caves in the past. Locations of some of these cave systems are presented in Figure I-6.

The caves in the Central Kentucky Karst are composed of two main components - horizontal passages and vertical shafts. The horizontal passages tend to form along bedding plane partings in the low dip limestones. Vertical shafts are cavernous voids often nearly cylindrical, with perfectly vertical walls. Whereas the horizontal passages form near or below the water table and act as primary paths for the movement of ground water, the vertical shafts form in the vadose zone and form the primary flow paths for water descending from the perched aquifers to the base level. Although vertical shafts frequently intersect horizontal passages, such intersections need not be genetically related and the horizontal passage can be much older than the vertical shafts. Caves formed high on the ridges usually do not have active streams whereas caves under the Sinkhole Plain and caves at low elevations within the ridges contain active present-day drainage. Portions of the upper level caves which are exposed beyond the caprock are usually wet from infiltrating waters and both active vertical shafts and active deposition of dripstone and flowstone is found in this environment. Passages at higher levels which extend beneath the sandstone caprock are usually dry. It is in this deep environment, protected from infiltrating waters, that gypsum and rare sulfate minerals are found.

The caves in the area are usually closely related to present and past underground drainage patterns. Each vertical shaft and many sinkholes have small drains, not always large enough to admit a human being. These drains aggregate into master drains which are found as cave passages of intermediate size. Master drains themselves aggregate into trunk drains which carry water from underground drainage basins to big springs. Some trunks are active today and these are largely flooded by the post-Pleistocene in-filling of the Green River channel. Paleo-trunks occur at higher levels and are the largest cave passages in the region. There is an obvious analogy between the arrangement of drains, master drains, and trunks to the arrangements of surface streams and rivers but the analogy must not be taken too far. Cave passages are closed pipes and the flow patterns are not the same in detail as the flow pattern in open channels of surface streams.

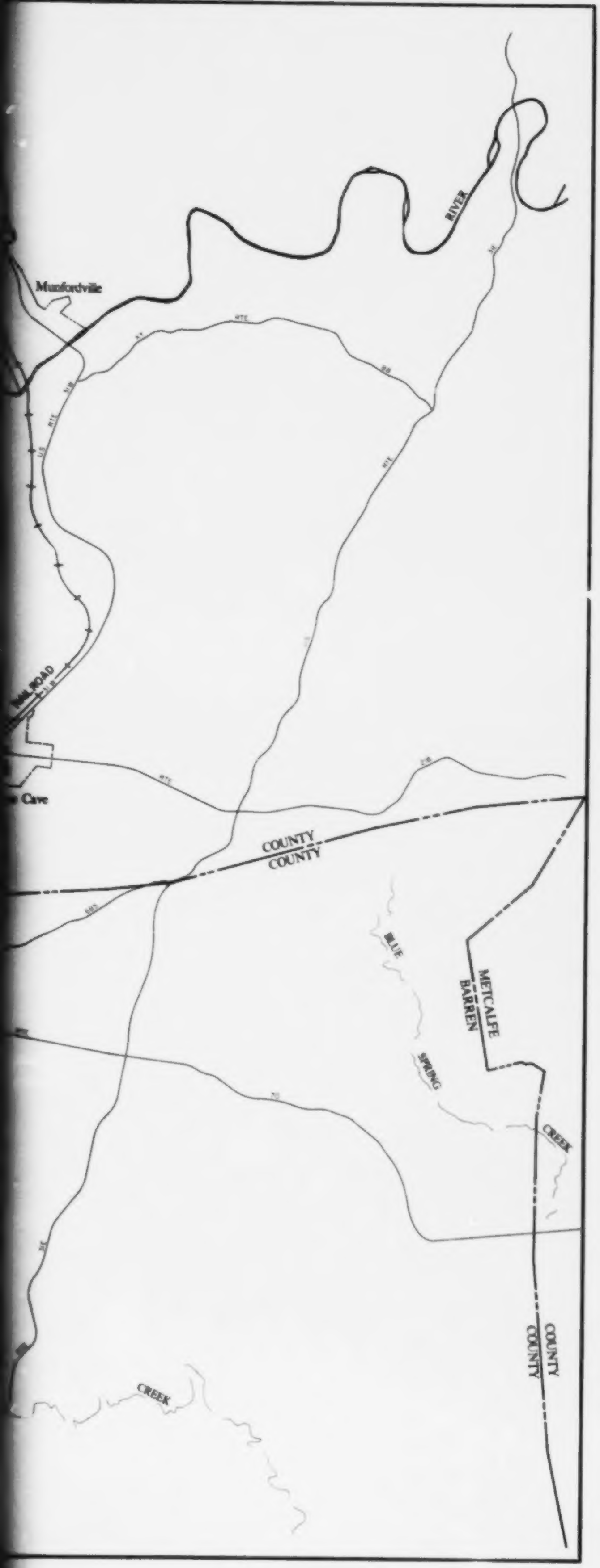
The overall drainage pattern of the caves is obscured by the closing of cave passages due to silting and to major rockfalls known as terminal breakdowns. The pattern of higher level passages is not directly related to present day topography, particularly the caves under the cuesta, and the downcutting of surface valleys produces the weakening of the cavern ceilings that leads to collapse.

The cave passages are depositional sites for minerals, some deposits of which have great scenic attraction. Certain of these, particularly the rare sulfate minerals, are stable within only a narrow range of temperature and relative humidity, and would be easily damaged by any changes in the cavern environment. Minerals so far identified in the caves of the study area include (Freeman et. al., 1973):


N
HART
EDMONSON
COUNTY
COUNTY
MAMMOTH
CAVE
NATIONAL
PARK
GREEN
RIVER
GREEN
Munfordville
14
1
Mammoth Cave
13
7
6
RAILROAD
8
Horse Cave
12
HART
BARREN
10
11
COUNTY
COUNTY
Cave
City
2
5
NASHVILLE
3
4
Park City
EDMONSON
WARREN
LOUISVILLE
AND
9
COUNTY
COUNTY
EDMONSON
BARREN
LITTLE
SINKING
CREEK
COUNTY
COUNTY
WARREN
BARREN
BEAVER
CREEK

A

I-10-a


Munfordville
RIVER
RAILROAD
Cave
COUNTY
COUNTY
BLUE
SPRING
CREEK
METCALFE
BARREN
COUNTY
COUNTY
CREEK

LEGEND

▨ MAMMOTH CAVE NATIONAL PARK

▲ COMMERCIAL CAVES - OPEN TO PUBLIC
1. MAMMOTH CAVE
2. DIAMOND CAVERNS
3. HUNDRED DOMES CAVE
4. JESSE JAMES CAVE
5. CRYSTAL ONYX CAVE
6. MAMMOTH ONYX CAVE

● NON-COMMERCIAL CAVES
7. CRUMPS CAVE
8. HIDDEN RIVER CAVE
9. PARKER CAVE
10. PROCTOR CAVE
11. SMITH VALLEY CAVE
12. LEE CAVE
13. COLOSSAL CAVE
14. GREAT ONYX CAVE

FIGURE I-6

MAMMOTH CAVE AREA
201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

CAVE SYSTEM LOCATIONS

12,000 6000 0 12,000 24,000
Scale In Feet

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia

B

Calcite	$CaCO_3$
Aragonite	$CaCO_3$
Hydromagnesite	$4MgCO_3.Mg(OH)_2.4H_2O$
Gypsum	$CaSO_4.2H_2O$
Epsomite	$MgSO_4.7H_2O$
Hexahydrite	$MgSO_4.6H_2O$
Mirabilite	$Na_2SO_4.10H_2O$
Celestite	$SrSO_4$
"Labile Salt"	$2Na_2SO_4.CaSO_4.2H_2O$
Blödite	$MgSO_4.Na_2SO_4.4H_2O$

The "labile salt" on the list is a previously undescribed mineral found as a minor phase in a highly mineralized passage in the Flint Ridge Cave System.

Cave entrances in the study area are easily closed by natural processes and the number of entrances is small in proportion to the great length of passage in the Cuesta caves. The high level portions of these caves that have large natural entrances, for example the historic entrance to Mammoth Cave and the entrance to Great Salts Cave (part of the Flint Ridge Cave System) were used by pre-historic man. The pre-Columbian explorers reached distances of several miles into the caves apparently to extract gypsum and other minerals. The high dry passages are a rich source of archaeological materials (Watson, 1974).

Below are listed the ten largest caves in the study area. Length data are taken from Cave Research Foundation Annual Reports.

The Flint Mammoth Cave System Length = 190.77 miles

Located beneath Flint Ridge and Mammoth Cave Ridge. The longest cave in the world and central showpiece of Mammoth Cave National Park. Two cave systems connected by a single passage. Mammoth Cave consists of a single drainage line with three major super-imposed trunks and many associated passages. There is an active streamway at the lowest level. The Flint Ridge System has several major drainage lines and less-clearly defined superimposed levels. The systems great complexity is achieved by superposition of valley drains, piracy routes, and vertical shaft drain systems.

Great Onyx Cave Length = 2.78 miles

Located on the northwest end of Flint Ridge and apparently truncated from the system by a surface valley. Two large and some minor passages and shafts. There is no large active stream system in this cave.

Proctor Cave Length = 6.36 miles

Located on Joppa Ridge. Entrance complex of passages connected by half mile long small passage with a fragment of trunk passage. Most of cave is high in ridge and not connected with active stream systems.

Lee Cave Length = 7.55 miles

Located on Joppa Ridge near Green River. The cave consists of a 1.5 mile trunk passage and 6 miles of smaller tubes and canyons. Much of the cave is above base level. Archaeological remains occur in the trunk passage.

Smith Valley Cave Length = 1.63 miles

Located in the dissected cuesta beneath Smith Valley and Cedar Spring Valley. Largest of several caves opening from Cedar Sink. Low level passage that carries tributary stream.

Crumps Cave Length = 9.5 miles

Located on northern edge of Fisher Ridge. Cave consists of two subparallel trunk passages, many active or abandoned tributaries and abandoned diversion passage. No active streams or base level passages are known. Present and paleo-flow is toward Lawler Blue Hole spring.

James Cave Length = 5.75 miles

Located on edge of Chester Escarpment above Park City. Extremely complex maze cave with great passage length within small area. Mostly upper level passage. Cave survey has not been published.

The Hidden River System Length = 15.75 miles

Located beneath karst valley northeast of Horse Cave. Master drain system for large catchment area including Horse Cave area. Interconnected cave with downstream distributary system and many spill-over routes so that flow paths are very sensitive to exact ground water stage.

Parker Cave Length = 4.17 miles

Located beneath Sinkhole Plain east of Park City. Collector or tributary system for drainage from more than a dozen small sinkhole and sinking stream catchment areas. Active streams throughout cave. Passages on two closely spaced levels.

Graham Spring System Length = 1.7 miles aggregate

Three separate caves beneath Sinkhole Plain southwest of Sinks Grove. Largest is Sinks Grove Cave, a dry abandoned trunk at 500-550 feet elevation. Wolf Sink Cave and Graham Springs Cave are shorter level trunk passages carrying the main discharge westward to Graham Spring.

Environmental Sensitivities

The most important scenic, recreational, and wilderness resource of the Central Kentucky Karst is the caves. There is the Flint Mammoth System, the longest cave in the world. There are many other caves, large and small, that are a significant scenic and recreational resource. There are the show caves that contribute to the tourist industry of the region. Because caves are limited in size and because the natural processes of oxidation, bacterial action and decay that serve to restore surface environments operate very slowly or not at all in a cave, the cave environment is very sensitive to intrusion of pollutants from the surface.

Pollutants can invade caves from above by direct infiltration of surface water or the pollutants can travel laterally through low level stream passages.

The threats to the caves are three: (1) Loss of scenic value due to contamination of the cave air or streams by pollutants, (2) Damage to aquatic and terrestrial life forms, and (3) Damage to mineral deposits and other special features. The intensity of the threat varies with individual caves depending on their topographic situation, internal geometry, presence or absence of streams, and presence or absence of sensitive features.

Most readily threatened by sewage, septic tank effluent, industrial wastes, other waste disposal practices (e.g. landfills and dumping), and non-point pollution sources (e.g. agricultural runoff, highway and railroad spills, etc.) is the horizontal drainage zone of caves. There is also a threat to the vertical drainage zone if sources of pollutants are located on the slopes or ridge tops above the cave. Some of the most scenic cave deposits occur in the zone of vertical drainage where the protective caprock is not present. For further discussion of the wilderness value of caves see Davidson and Bishop (1971).

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7. SOILS

There are nine soil associations in the study area (Figure I-7). The information was obtained from individual district soil conservationists of the Soil Conservation Service, U. S. Department of Agriculture. Only the soils of Barren County have been studied and described in a County Soil Survey. Consequently, the soil associations are slightly different from one county to another. The soil associations, their limitations and the degree of the limitation according to SCS criteria are described in Table I-2. The soil interpretations are general and are only helpful in planning on a regional, county or community level. For information on particular sites, a more detailed survey such as the SCS county survey is required.

Physical Characteristics

Baxter-Bedford

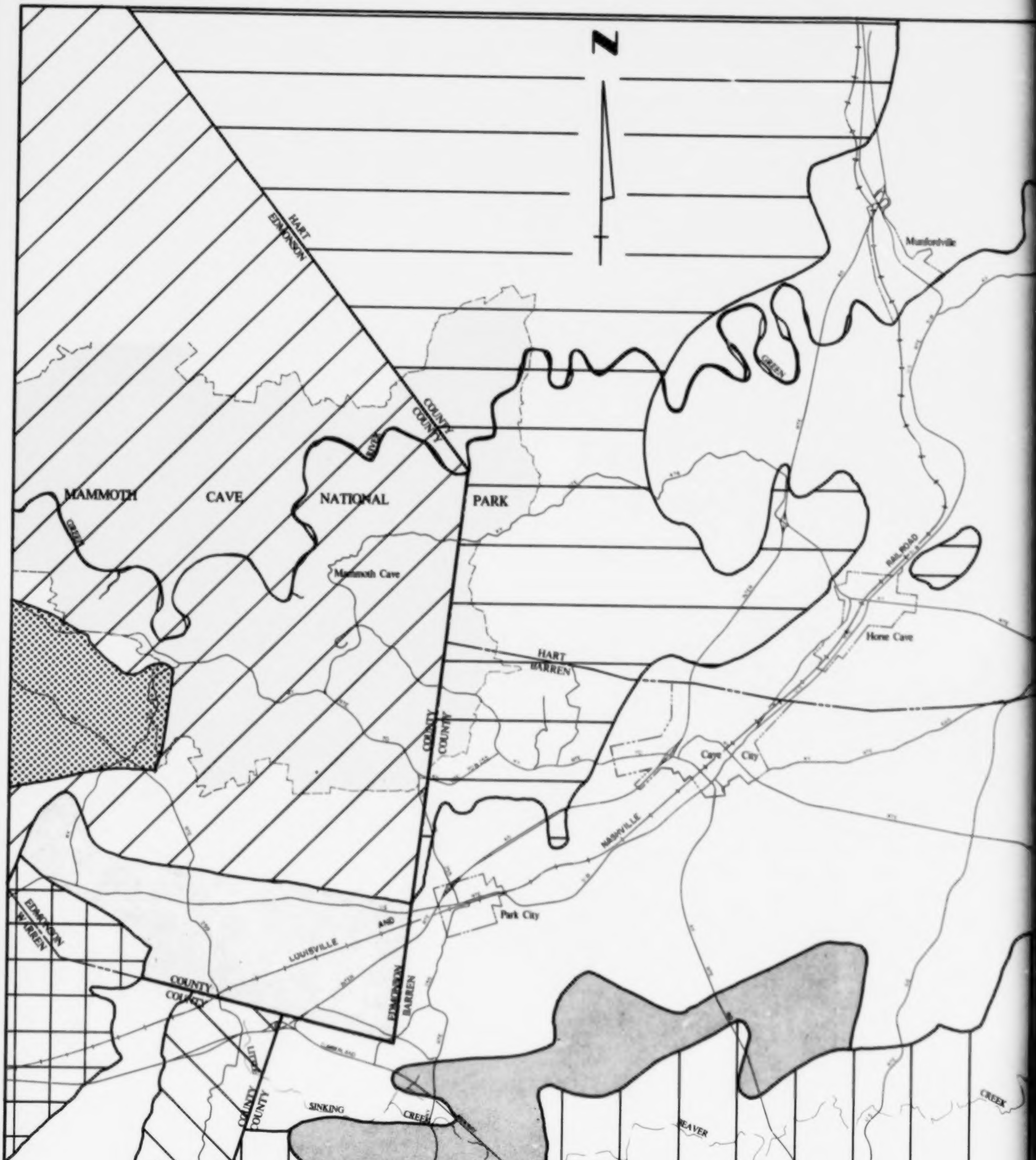
The Baxter - Bedford association is commonly found on hilly, karst areas and gently sloping uplands. These soils are useful for pasture, cropland and some woodland. Baxter soils occur on the hilly and karst areas. These soils have a brown cherty silt loam top layer and a red cherty clay subsoil over residuum from cherty limestone. Bedford soils occur on the gently sloping areas. These soils have a brown silt loam top layer and a yellowish-brown loam subsoil. The substratum consists of several feet of clayey limestone residuum.

Baxter-Talbott-Dickson

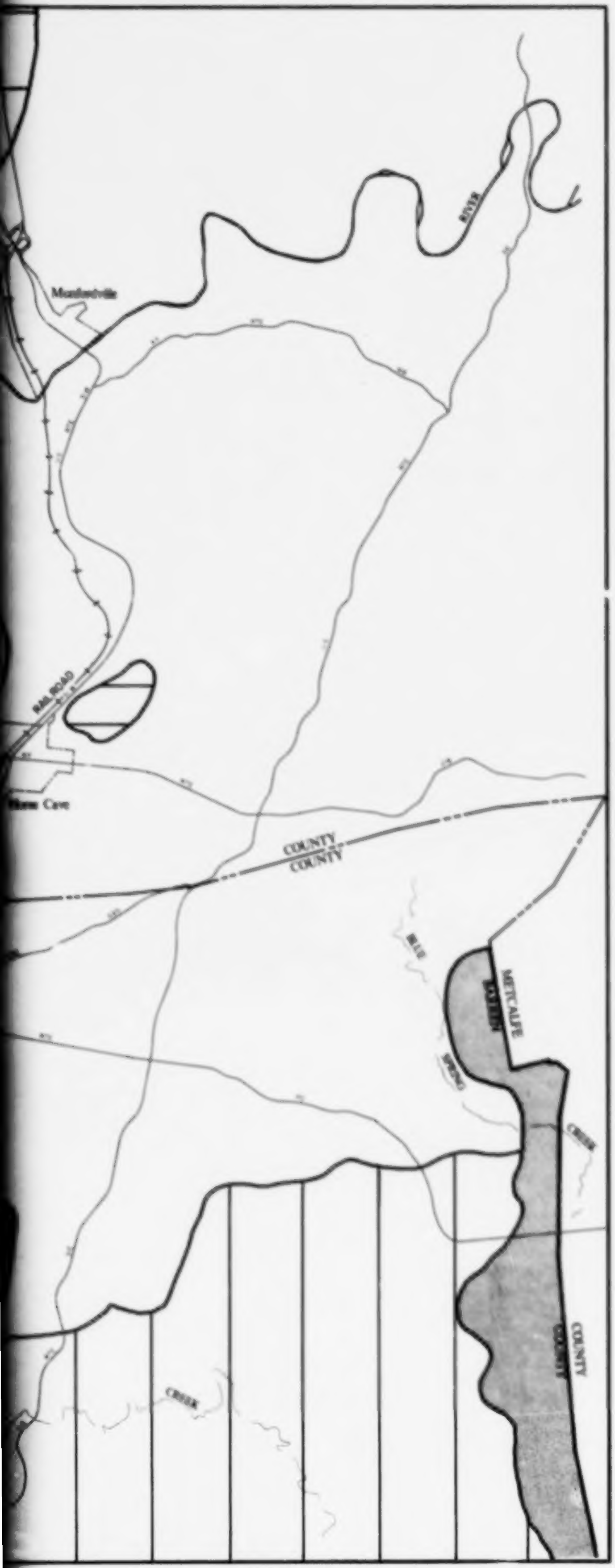
The Baxter-Talbott-Dickson association is made of deep, well drained, dominantly cherty soils with clayey subsoils on uplands. On ridgetops the soils are moderately deep, moderately well drained silty soils. In some places karst topography is dominant. The Baxter series consists of cherty or rocky well-drained soils that developed from cherty limestone. The upper subsoil is strong-brown or yellowish red, firm cherty silty clay loam. Rock outcrops are common on steeper slopes. The soils are difficult to till and most farming consists of row crops, hay and pastures. Woodlands are on the steeper slopes. The Talbott series consists of well drained, clayey soils on uplands. These soils are gently to strongly sloping. They developed in residual material from limestone and shale. These soils are difficult to till because the surface layer is finely textured. About 80 percent of the acreage is used for crops, hay and pasture. The rest is wooded. The Dickson series consists of acid, moderately well-drained, level to sloping soils of the uplands. These soils developed in part from residual material from limestone and in part from wind blown silt. Dickson soils are easily tilled and most of the acreage is used for cultivated crops, hay and pasture.

Caneyville-Zanesville-Weikert

The Caneyville-Zanesville-Weikert association is composed of upland soils found on broad ridge tops. Most of this soil association is in the Mammoth Cave National Park and is either idle or in forest. A few acres of row crops are grown on the gentle slopes outside the park. The remainder is in hay or pasture with some wooded areas. Caneyville soils have a brown silt loam surface and a brown reddish-brown silty clay subsoil. The soil is well drained, is usually found on steep slopes and may have numerous rock outcrops. Zanesville soil has a brown silt loam surface layer and a brown heavy silt loam subsoil underlain by a thin fragipan. Weikert soils have a dark brown shaly


N
HART
EDMONSON
COUNTY
COUNTY
MAMMOTH
CAVE
NATIONAL
PARK
GREEN
CREEK
Mammoth Cave
Munfordville
RAILROAD
Horse Cave
HART
BARREN
COUNTY
COUNTY
Cave City
NASHVILLE
Park City
LOUISVILLE
AND
EDMONSON
BARREN
COUNTY
COUNTY
EDMONSON
BARREN
SINKING
CREEK
BEAVER
CREEK
COUNTY
COUNTY
WARREN
BARREN

A


Munfordville
RIVER
RAILROAD
Cave
COUNTY
COUNTY
BLUE
SPRING
CREEK
METCALFE
BARREN
COUNTY
COUNTY
CREEK

LEGEND

▒ MAMMOTH CAVE NATIONAL PARK

▧ BAXTER - BEDFORD

▥ BAXTER - TALBOTT - DICKSON

▨ CANEYVILLE - ZANESVILLE - WEIKERT

□ CUMBERLAND - BEDFORD

□ CUMBERLAND - PEMBROKE

▒ DICKSON - MELVIN - CRIDER

▦ PEMBROKE - CRIDER

▩ SADLER - JOHNSBURG

▤ WEIKERT - CANEYVILLE - WELLSTON - ZANESVILLE

NOTE: ABRUPT CHANGES IN SOIL ASSOCIATIONS OCCUR AT COUNTY LINES BECAUSE SOILS HAVE NOT BEEN THOROUGHLY STUDIED IN EDMONSON, HART AND WARREN COUNTIES. THE MAP ACCURATELY REPRESENTS THE INFORMATION SENT BY EACH COUNTY'S SOIL CONSERVATIONIST.

FIGURE I-7

MAMMOTH CAVE AREA
201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

SOILS ASSOCIATIONS

12,000 6000 0 12,000 24,000
Scale In Feet

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia

B

silt loam surface and a yellowish-brown very shaly silt loam subsoil to a depth of 20 inches or less of the surface.

Cumberland-Bedford

The Cumberland-Bedford association has developed from limestone. Much of the area is karst topography. Because the soils are deep, the area is suitable for row crops. Cumberland soils have a dark reddish-brown cherty silt loam surface and a dark red subsoil of approximately 5 feet width. Bedford soils have been previously described.

Cumberland-Pembroke

The Cumberland-Pembroke association consists of soils that are deep, well-drained, gently to strongly sloping clayey or loamy soils of the limestone uplands. This association makes up about one-third of the study area. It is a karst area having narrow ridges and intervening bowl-shaped sinks. The association is suited to the production of all crops that are grown locally. Cumberland soils have been previously described. Pembroke soils occur on gentle slopes and some strongly sloping karst areas. These soils have a dark brown silt loam layer and red clayey subsoil over residuum from high grade limestone.

Dickson-Melvin-Crider

The Dickson-Melvin-Crider association consists of moderately deep, moderately well drained, gently sloping silty soils of the uplands. On the flood plains soils are poorly drained, level, and silty. About 60 percent of this association is used for corn, tobacco, alfalfa, hay and pasture. The poorly drained areas are mostly wooded. Dickson soils have been previously described. Melvin soils are the nearly level, poorly drained soils of the flood plains. The soils are formed in alluvial materials derived chiefly from limestone, shale and sandstone. Crider soils are common on gently sloping higher elevated areas. These soils have a brown silt loam layer with the upper subsoil of brown silty clay loam and the lower subsoil of reddish clay. The soils are formed in wind deposited silts and limestone residuum.

Pembroke-Crider

The Pembroke-Crider association is on broad, gently rolling and slightly karst areas. The soils are developed from high grade limestone with loessal influence. These soils are well suited for row crop farming. Both Pembroke and Crider soils have been described previously.

Sadler-Johnsburg

The Sadler-Johnsburg association is made up of moderately well-drained to somewhat poorly drained soils on level to gently rolling topography. These soils have developed from sandstone, silt stone and shale. The soils are suitable for corn, soybeans, pasture and hay. A high water table and fragipan place limitations on the uses of these soils. Sadler soils have a grayish-brown silt loam surface and a yellowish-brown silt loam subsoil underlain by a silt loam fragipan at 18 to 24 inches from the surface. Johnsburg soil has a light brownish-gray surface layer and a yellowish-brown subsoil underlain by a gray mottled silty clay loam fragipan at approximately 18 inches.

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Weikert-Caneyville-Wellston-Zanesville

The Weikert-Caneyville-Wellston-Zanesville association is composed of soils that are shallow and moderately deep, well drained, sloping to steep and rocky on hillsides. On ridgetops the soils are deep, moderately to well drained, and made of gently sloping loam. Steep slopes, stone and rocks limit these soils. Most of the association is in woods of low commercial value. The association has low potential for crops and pasture. Weikert, Caneyille, and Zanesville soils have been previously described. Wellston soils are deep well-drained soils of the uplands. These soils developed partly in wind blown silt and partly in residual material derived from siltstone, shale and sandstone. The surface layer is a brown silt loam. The upper subsoil is yellowish brown silt loam and light silt clay loam which changes with depth to a strong-brown firm silty clay loam. Wellston soils are suitable for crops.

Soil Suitabilities for On-Lot Disposal

The Soil Conservation Service, U. S. Dept. of Agriculture, defines the limitations of soils for on-lot disposal based on the properties and criteria listed in Table I-3. A slight rating means those soils have properties suitable for operation of conventional on-lot disposal systems. A moderate rating means that the soils are somewhat limiting to the operation of the absorption field. These soils require careful planning and design of the absorption area to compensate for the limitation imposed by the soils. These soils may be suitable for alternate on-lot disposal systems. Soils rated severe have physical properties that cannot be modified to insure continued satisfactory operation of the system.

On June 6, 1978, Kentucky passed its regulations for subsurface sewerage disposal systems. The criteria established by the Commonwealth are not as conservative as those established by the SCS. According to Kentucky's regulations, depth to bedrock should be equal to or greater than four (4) feet, the depth to seasonal high water table should be equal to or greater than four (4) feet and permeability should be at least one (1) inch per hour although faster rates are permissible if longer drainage fields are used. No criteria were established for slope. The Kentucky regulations are similar to the criteria set by the SCS for moderate limitations to conventional on-lot disposal systems (Table I-3).

According to the SCS criteria, all soil associations in the study area have soils with severe limitations for on-lot disposal systems. However, within each soil association there are soils suitable for either conventional or alternate on-lot disposal systems. The degree of the limitation (slight, moderate, severe) of each property for each soil series is included in Table I-2. In Table I-2 slope is presented as a range. Therefore, where the limitation is expressed as a range (e.g., slight to moderate) there would be soils within the soil series that are suitable for on-lot disposal methods. In addition, these soil limitations can be overcome by a number of engineering techniques such as providing elevated sand mounds, increasing the size of the absorption field, adding soils or using aerobic tanks. Soils must be examined on a site specific basis to determine their suitabilities for on-lot disposal systems. Soils within the Baxter, Talbott, Cumberland, Pembroke, and Crider soil series appear suitable for some type of on-lot disposal system. The information presented here is suitable only for making regional or areawide planning decisions.

TABLE I-3

CRITERIA FOR ESTABLISHING SOIL SUITABILITIES FOR CONVENTIONAL ON-LOT DISPOSAL[*], SOIL CONSERVATION SERVICE, U.S. DEPT OF AGRICULTURE.

PROPERTY	LIMITS SLIGHT	MODERATE	SEVERE	RESTRICTIVE FEATURE
1. USDA TEXTURE	---	---	ICE	PERMAFROST
2. FLOODING	NONE, PROTECTED	RARE	COMMON	FLOODS
3. DEPTH TO BEDROCK, CEMENTED PAN OR IMPERMEABLE LAYER (FT)	>6	3.3-6	<3.3	DEPTH TO ROCK OR CEMENTED PAN
4. DEPTH TO HIGH WATER TABLE (FT)	---	---	+	PONDING
	>6	4-6	0-4	WETNESS
5. PERMEABILITY (IN/HR): (24-69")	2.0-6.0	I/0.6-2.0	<0.6	PERCS SLOWLY
ALL LAYERS BELOW 24"	---	---	>6.0	POOR FILTER
6. SLOPE (PCT)	0.8	8-15	>15	SLOPE
7. 1/FRACTION 3 IN (WT PCT) (WEIGHT PERCENT)	<25	25-50	>50	LARGE STONES

---

[*] Septic tanks and tile fields

I/Recheck to see if rating should be SLIGHT.

1/Weighted average to 40 inches.

Source: U.S. Department of Agriculture, Soil Conservation Service.

In the study area itself, careful analysis of the Barren County soil maps has shown that the soils in and to the east of Park City and Cave City may be suitable for alternate and/or conventional on-lot disposal systems. These soils, members of the Cumberland-Pembroke association, continue into Hart County (Figure I-7). Although detailed maps of Hart County soils are not available, those soils around and to the east of both Horse Cave and Munfordville, may also be suitable for on-lot systems.

Soil Suitabilities for Land Application

Soils can be categorized for their suitabilities for land application based on slope, soil texture, depth to bedrock, depth to water table, pH, soil permeability, and potential for flooding (Table I-4). For overland flow slopes should be uniform between 2% and 8%. Spray irrigation on wooded terrain can be adapted to slopes of less than or equal to 30% if proper runoff and erosion controls are instituted; however, soils of slope 12% or less are preferrable. Loamy soils are preferred although sandy to clay loam textures are acceptable. Overland flow is useful where soil permeability is slow and/or the groundwater table is high because the water does not move down through the soil profile. Spray irrigation requires a more permeable soil, and depth to water table should be at least 5 feet.

In the Mammoth Cave study area Pembroke-Crider soils appear to be well-suited for spray irrigation, and Pembroke soils of less than 12% slope in the Cumberland-Pembroke association may be suitable (Figure I-8). This must be examined on a more site specific basis before a site can be chosen for spray irrigation.

Soil factors that limit the use of septic tanks, spray irrigation and overland flow disposal methods in the area are listed by soil association and soil series on Table I-5. Where slope has been listed as the limiting factor for on-lot disposal methods, it should be noted that there are soils of that type that are suitable. The limitations have not been rated for spray irrigation or overland flow. Slope is the major soil factor limiting the use of overland flow as a disposal method.

8. SURFACE WATER RESOURCES

The major surface water in the study area is the Green River. Of the twelve river basins in Kentucky, the Green River Basin is the largest. Augmented by upstream impoundments, the minimum 7-day, ten-year low flow is estimated to be 159 cfs at Munfordville and 392 cfs at Brownsville, just downstream of the study area. Average stream discharge at these stations is 2,598 and 4,253 respectively.

In the study area, the Green River serves as both a wastewater receiving stream and a water supply. Wastewater treatment plants at Munfordville and Mammoth Cave National Park discharge to the Green River while the raw water intake for the Edmonson County Water District is located downstream at Brownsville, Kentucky. In addition, the Mammoth Cave National Park Master Plan calls for using the Green River as the source of water supply to serve the Park in the future.

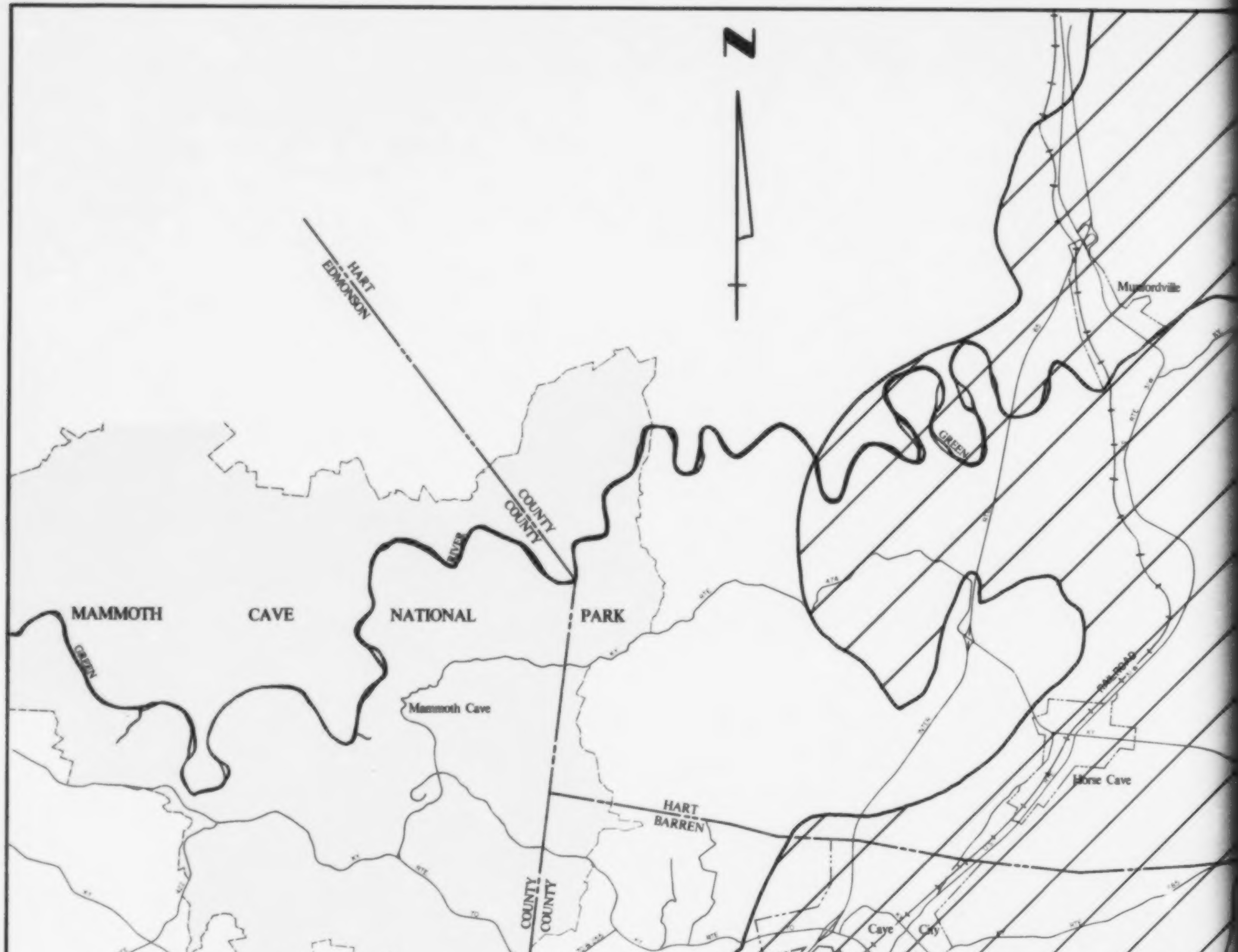
Because the river has a large assimilative capacity and upstream development is not extensive, the water quality of the Green River in the study area is

TABLE I-4

SOIL FACTORS REQUIRED FOR SPRAY IRRIGATION AND OVERLAND FLOW

	Spray Irrigation	Overland Flow
Slope	≤ 12%up to 30% is acceptable in wooded areas.	uniform 2-8%
Soil Texture	loamy (sandy-loam) (clay-loam)	non-sandy soils
Depth to bedrock	≥ 5 feet	≥ 5 feet
Depth to Watertable	≥ 5 feet	can be a high water table
pH	6-7 (neutral)	6-7 (neutral)
Flooding	non-flood prone areas	non-flood prone areas
Soil permeability	highly permeable soil	slow permeability

Source: EPA Technology Transfer Seminar Publication, Land Treatment of Municipal Wastewater Effluents, Design Factors II.


N
HART
EDMONSON
COUNTY
COUNTY
MAMMOTH CAVE NATIONAL PARK
GREEN
RIVER
GREEN
Munfordville
Mammoth Cave
RAILROAD
HART
BARREN
Horse Cave
COUNTY
COUNTY
Cave City
NASHVILLE
Park City
EDMONSON
WARREN
LOUISVILLE
AND
COUNTY
COUNTY
EDMONSON
BARREN
LITTLE
COUNTY
COUNTY
SINKING
CREEK
BEAVER
WARREN
BARREN

A

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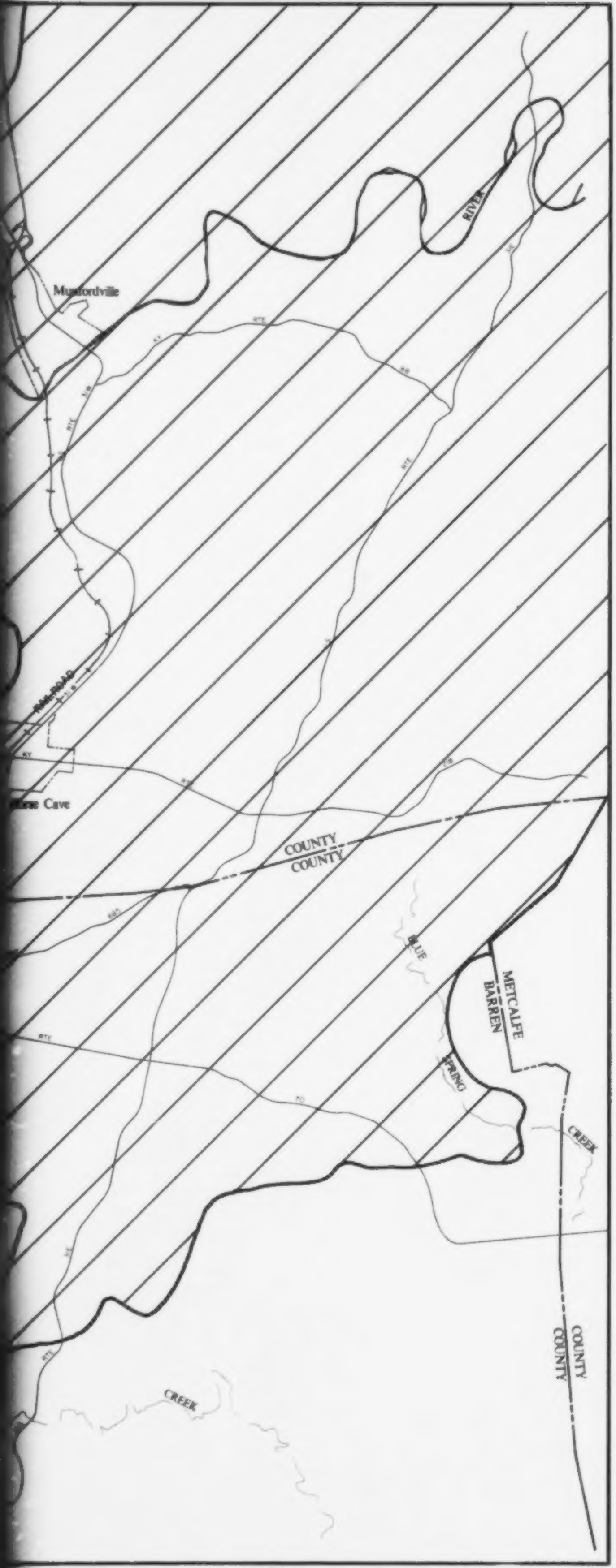
Munfordville
RIVER
RTE
KY
RAILROAD
Cave
COUNTY
COUNTY
BLUE
METCALFE
BARREN
SPRING
CREEK
COUNTY
COUNTY
CREEK

LEGEND

▒	MAMMOTH CAVE NATIONAL PARK
☐	SOILS UNSUITABLE FOR SPRAY IRRIGATION
▨	SOILS WITHIN ASSOCIATION MAY BE SUITABLE FOR SPRAY IRRIGATION
▧	SOILS SUITABLE FOR SPRAY IRRIGATION

FIGURE I-8

MAMMOTH CAVE AREA
201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

SOIL SUITABILITY FOR SPRAY IRRIGATION

12,000 6000 0 12,000 24,000
Scale In Feet

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia

B

considered to be generally good. However, water quality data compiled by the Kentucky Division of Water Quality from 1970 to 1974 (Table I-6) indicate that lead concentrations in the Green River at Munfordville exceed Kentucky Water Quality Standards for raw drinking water. The mean value only slightly exceeds the standard, but the maximum reading of 0.77 mg/l is approximately fifteen times greater than the standard. From the size of the standard deviation, s, it appears to be upstream of the study area, but it is not identified at this time. Furthermore, there are no more recent data available to determine if these water quality violations continue. According to Kentucky Division of Groundwater personnel, investigations of the problem have been curtailed since Munfordville no longer is using the Green River as a water supply.

Although mean values for other water quality parameters were within water quality standards, maximum values for several parameters (conductivity, total dissolved solids, chlorides and iron) violated existing or proposed water quality standards. Upon inspection of mean and standard deviations of sampling data, these high values are rare occurrences. Conductivity, chlorides and total dissolved solids are expected to exceed values set by water quality standards in less than 0.11% of samples taken. Iron data is not as extensive, but water quality violations are expected to be rare. The maximum value reported is only 0.03 mg/l greater than the standard.

In addition to the water quality violations at Munfordville, fecal coliform violations were reported near Greensburg, Kentucky in July, 1968. With the exception of lead, none of these water quality violations appears to present a serious threat to water quality.

The water quality parameters measured at Munfordville are some of the inorganic constituents of the water. However, no biological or biologically related parameters are noted. Dissolved oxygen, most important for maintaining fish propagation, is not recorded. According to the River Basin Water Quality Management Plan for Kentucky (1975), no dissolved oxygen standard violations were reported for the section of the Green River in the study area.

Other than the Green River, there are few surface streams in the study area because of the hydrologic conditions associated with the karst geology. Surface runoff from the higher elevations flows north toward the Green River, sinks at the south and east margin of the sinkhole plain and then forms cave streams. As these streams continue to flow beneath the sinkhole plain to the Green River they are also fed by runoff into sinkholes and direct infiltration. Thus, in the study area, there are no surface tributaries to the Green River.

There are only three surface streams in the study area that are mapped - Beaver Creek, Little Sinking Creek and Spring Creek. Beaver Creek flows to the south of the study area. It is not considered to be of significance to this study since it is tributary to the Barren River and has little or no bearing on activities in the study area. Spring Branch (Blue Spring Branch) flows in the eastern portion of the study area. This stream is the major tributary to the east Branch of Hidden River Cave System. Little Sinking Creek flows in the southwest portion of the study area and sinks near the intersection of the Cumberland Parkway and Rt. 259. Normally, Little Sinking Creek flows to the Green River, but, in floods, a portion of the flow goes to the Barren River Basin. Sinking Creek is a major surface tributary to a cave system that is part of the subsurface drainage to Mill Hole.

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There are no USGS streamflow data for Spring Creek or Little Sinking Creek. According to USGS, because of the nature of surface streams in a karst area, stream flow is expected to fluctuate greatly, with high flow during wet-weather or snow melt periods and near zero discharge during dry-weather base flow. Because of the nature of fluctuating flows and minimum discharge during base-flow, these streams are not considered valuable water resources. However, they are considered important because they carry surface runoff to the cave systems.

9. SUBSURFACE WATER RESOURCES

Hydrogeology

The ground water system and overall hydrologic arrangement for the Central Kentucky Karst are illustrated in Figure I-9. The discussion that follows draws heavily on the report of Hess and White (1974). See also the reports of the U.S. Geological Survey (Brown and Lambert, 1963; Cushman et. al., 1965; Brown 1966) for more detail on the hydrogeology of the study area.

The Green River, 50 to 100 feet wide and usually less than 25 feet deep, extends some 40 miles between Munfordville and Brownsville. The Green River is the hydrological base level for the region and receives most ground water discharge from the study area.

There are five major sources for the water that discharges into the base level stream. (1) The sinking streams that contribute water from the southern edge of the Sinkhole Plain (2) direct infiltration (sometimes called internal runoff) through the sinkholes on the Sinkhole Plain (3) precipitation that falls on the clastic cap rock-protected ridges recharges the perched Haney limestone and Big Clifty sandstone aquifers which then re-emerges to enter the main limestone aquifer (4) direct infiltration through sinkholes in the karst valleys that dissect the plateau and (5) water from Green River that backfloods into the base level aquifer.

The water collected on each of the types of catchment area (except for baselevel backflooding) is separated into three components. Evapotranspiration losses discharge some of the water back into the atmosphere. The remaining water enters the underground system since no surface runoff reaches the river. It has been separated into two components: a sinking stream or internal runoff component and a diffuse or infiltration component. The infiltration component enters the vadose zone through small pores and fractures and eventually reaches the saturated zone to become part of what has been labeled the "fracture and pore" system. This is the portion of the ground water that would be sampled by an arbitrarily chosen well, providing that the well did not intersect a conduit. The surface drainage basins, the large sinkholes, and the karst valleys all serve to concentrate the water as runoff before it enters the ground water system. The water then enters the ground at a very localized swallow point.

Drainage from the Plateau tops provides recharge for a perched aquifer that exists in the Haney limestone and Big Clifty sandstone and which can be tapped by shallow wells. Evidence from the cave system suggests that there is very little vertical seepage through the capped portions of the ridges. The cave systems are generally dry and devoid of secondary calcite deposits usually associated with vertical seepage. Travertine deposits exist only in cave passages that extend toward the valley sides beyond the caprock. Both the surface

CENTRAL KENTUCKY KARST HYDROLOGIC ARRANGEMENT

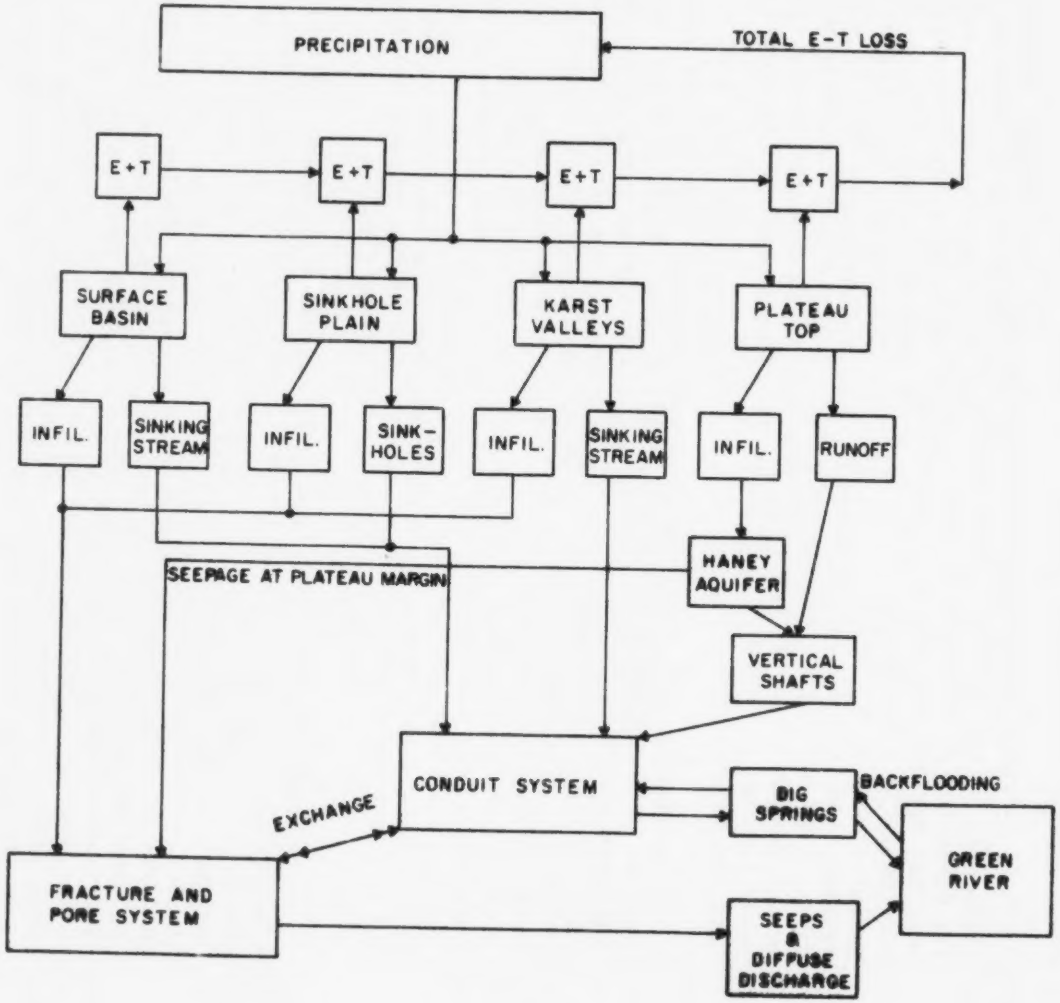

PRECIPITATION
TOTAL E-T LOSS
E+T
E+T
E+T
E+T
SURFACE BASIN
SINKHOLE PLAIN
KARST VALLEYS
PLATEAU TOP
INFIL.
SINKING STREAM
INFIL.
SINK-HOLES
INFIL.
SINKING STREAM
INFIL.
RUNOFF
HANEY AQUIFER
SEEPAGE AT PLATEAU MARGIN
VERTICAL SHAFTS
CONDUIT SYSTEM
EXCHANGE
BIG SPRINGS
BACKFLOODING
GREEN RIVER
FRACTURE AND PORE SYSTEM
SEEPS & DIFFUSE DISCHARGE

FIGURE I-9

runoff that crosses the Big Clifty and the discharge from the Haney springs enter the lower limestone units at the margins of the caprock. Some crosses the vadose zone as slow seepage that results in the deposition of travertine. The bulk of the flow, however, is concentrated and bores its way to the base level by excavating huge vertical shafts. Vertical shafts drain into the conduit system through an intricate pattern of small tubes and canyons. The shaft drain complexes are frequently observed as an aggregating set of small free surface streams that can be mapped through junctions and confluences with increasingly larger volume until at last the flow reaches the water table and can no longer be followed (Brucker et. al., 1972).

All of these inputs aggregate together into the conduit system that feeds ultimately to the springs. Each spring, therefore, can be regarded as an outlet point for an underground drainage system of some degree of complexity. The regional springs are fed by large conduits carrying water from collector systems of surface basins and sinkhole areas many miles away. Closer to the river, valley drains from the karst valleys feed into the main system and shaft drain systems feed into the valley drains. Some valley drains lead to the river directly as springs of intermediate size, while shaft drain systems for small re-entrant valleys near the river may also drain directly to the river through small springs and seeps. Thus there is a large number of springs of diverse flow characteristics.

The sinking stream catchment is made up of an aggregate of many small surface catchments ranging up to a few mi^2 in area. Sinking Creek, Little Sinking Creek and Blue Spring Creek have several surface tributaries, but many are short first order streams. The sinking streams are incised up to 100 feet below the general level of the Sinkhole Plain and most of their extension out into the Plain in the incised blind valleys. The blind valleys are alluviated and the streams flow in irregular channels cut into the alluvial blanket. Most of the smaller streams are intermittent and flow only during periods of high runoff. The large streams usually have a sequence of swallow holes and during low runoff sink in their beds up to a mile upstream from the blind valley headwall. As flow increases they utilize more and more of the swallow holes until under flood conditions the entire blind valley may be flooded.

The sinking stream catchment area has three different soil associations. The Cumberland-Pembroke association is deep, well-drained, clayey or loamy soil on the limestone uplands. The characteristic red soils associated with karst topography occur in this association. The Dickson-Melvin-Crider Association is the second sinking stream catchment soil association. It is dominatly moderately deep, moderately well drained, gently sloping, silty soil on the uplands and poorly drained, nearly level silty soil on the flood plains. The third association is the Baxter-Talbott-Dickson Association. It is described as a deep, well drained, gently sloping to moderately steep, dominantly cherty soil with clayey subsoil on the uplands, and moderately deep, moderately well drained, gently sloping silty soil on the ridge tops (Latham, 1969).

Each sinkhole can be thought of as having its own catchment, usually only a fraction of an acre to a few acres. The main soil type on the Sinkhole Plain is the Cumberland-Pembroke Association. The red Cumberland soils occupy the well-drained interfluves between sinkholes while the sediments filling the sink bottoms are more yellow or brown.

Precipitation falling onto the sandstone-capped ridges recharges the perched Haney aquifer which in turn discharges as a series of springs and seeps along its line of outcrop. This water is then directed downward to the basal drainage system via vertical shafts. Where substantial areas of caprock occur, there may be enough accumulation of surface runoff to supply perennial streams which usually sink when they cross the Big Clifty sandstone onto the Girkin limestone. The Cuesta top has two soil types, the Wellston and the Zanesville. They are deep, well drained to moderately well drained, gently sloping to sloping, loamy soils with thickness of 3 to 6 feet. They are moderately permeable and have available water capacities of approximately 8 inches (Latham, 1969).

An unusual source or recharge for the karst aquifer is backflooding from the Green River. The various sources of recharge drain to the river through low gradient open conduits. The river stage of Green River fluctuates through more than 60 feet in its natural regime (moderated considerably since the construction of a dam at Greensburg upstream from the study area). Sudden rises in the river resulting from storms in the upstream reaches of the Green River Basin reverse the hydraulic gradients and cause water to flow into the springs. Since gradients are low, backflooding can force water into the aquifer for distances of several miles from the river. Reversal of spring flows was traced by the chloride concentrations in cave waters brought on by contamination of the Green River due to brine spills from the Greensburg oil field in the late 1950's (Hendrickson, 1961; Krieger and Hendrickson, 1960).

Non-Carbonate Aquifers

The geology and topography of the Chester Cuesta combine to create conditions for the formation of several perched aquifers above the basal water table. These zones are as follows: (1) a generally continuous ground water body in the Haney limestone perched on shale layers in the lower part of the Haney; (2) a generally continuous body of ground water in the Big Clifty sandstone perched on a shale at the base of the Big Clifty, and (3) discontinuous bodies of perched water above local shale beds near the top of the Girkin formation.

Ground water in the sandstones becomes more important in the western portion of the study area where the Cuesta is less dissected and the sandstone caprock more continuous. Here, the perched ground water in the Hardinsburg sandstone and in the Big Clifty sandstone can be tapped by shallow wells and produces sufficient water for domestic supplies.

The most reliable data on the Haney limestone aquifer comes from Flint Ridge where the formation is about 35 feet thick. Concentrated discharge from the Haney aquifer on Flint Ridge occurs at 8 known springs located typically at the head of deep re-entrants on the sides of the ridge. Haney springs occur in similar settings in other parts of the study area. The Flint Ridge springs are used as the water supply for Mammoth Cave National Park. The U.S. Geological Survey has monitored the flow of these springs (Cushman et. al., 1965) and finds a base flow of 0.16 cfs. This gives a specific base flow runoff through the springs of 0.04 cfs/mi^2 which is only 26% of the specific base flow runoff for the karst area as a whole, 0.15 cfs/mi^2. This indicates that most of the water is discharged as small seeps or is leaked downward into the underlying perched Big Clifty sandstone aquifer.

Underground Streams

The underground drainage in the karst follows well-defined flow paths which could be considered underground streams. The deep flow paths beneath the Chester Cuesta occur mostly as pipe flow in flooded conduits at depths of 10 to 30 feet below pool stage of Green River. These flow paths have not been observed directly except by divers very close to the spring mouths. Echo River in Mammoth Cave may be a rare exception. Valley drains and shaft drains at higher levels in the cave systems under the ridges appear as free surface streams flowing on rocky or silt-floored passages. These streams of water can in some instances be followed for distances of miles and often appear on cave maps as "rivers" (e.g. Bretz River and Candlelight River in the Flint Ridge System and Mystic River in Mammoth Cave). Cave streams on the Sinkhole Plain are often perched on impermeable chert horizons and appear as free-flowing streams in large cave conduits. In many caves, human attempts to explore the rivers ends in frustration either because the river flows into a highly permeable but humanly impermeable breakdown or ends in a sump. The continuity of these streams of water, however, is documented by the dye tracing experiments which show that there are distinct flow paths connecting the points where dye is injected and where it is detected.

Parker Cave provides an example of a cave system with a clearly defined tributary system in which feeders from different small catchments on the Sinkhole Plain aggregate together to form a master stream.

Distributary systems also exist commonly. An example is the Hidden River System, in which a single trunk flow is broken into a number of distributary channels so that a single source of water appears at more than one spring.

Many of the underground systems flood so that the streams flow in open channels during periods of low flow but flooded pipes appear during periods of high flow. Water levels can rise in the caves for distances of 80 feet or so. Rising water levels can be responsible for the spillover of water from one drainage system into another and can cause re-routing of both the flow and any pollutants carried by the water.

Springs

The outlet points for the water collected in the karst aquifer are a series of springs along the Green and Barren Rivers. Some springs are large, implying a large catchment area; others are small suggesting discharge of water from local sources. A listing of 81 springs on Green River between Munfordville and Brownsville has the distribution in discharges shown in Figure I-10. The larger springs are tabulated in Table I-7. The numbers identifying the springs are shown on Figure I-4.

The springs are of two types: Alluviated springs and gravity springs. The alluviated springs are developed below river level and have rise pools that are fed at depth. Pike and Turnhole Springs, two alluviated springs, have been examined by scuba divers, and both are fed from large conduits approximately 30 feet below pool stage of the river. Springs with unconfined outlets and free-flowing streams are gravity type springs. Alluviated springs are the most common and occur because of the filling the Green River channel with outwash material after the last glaciation. The outwash material dammed the low-lying solution conduits, flooding them, and forcing the water to discharge from rise pools created between the alluvial fill and the river bank.

DISCHARGE DISTRIBUTION OF GREEN RIVER SPRINGS

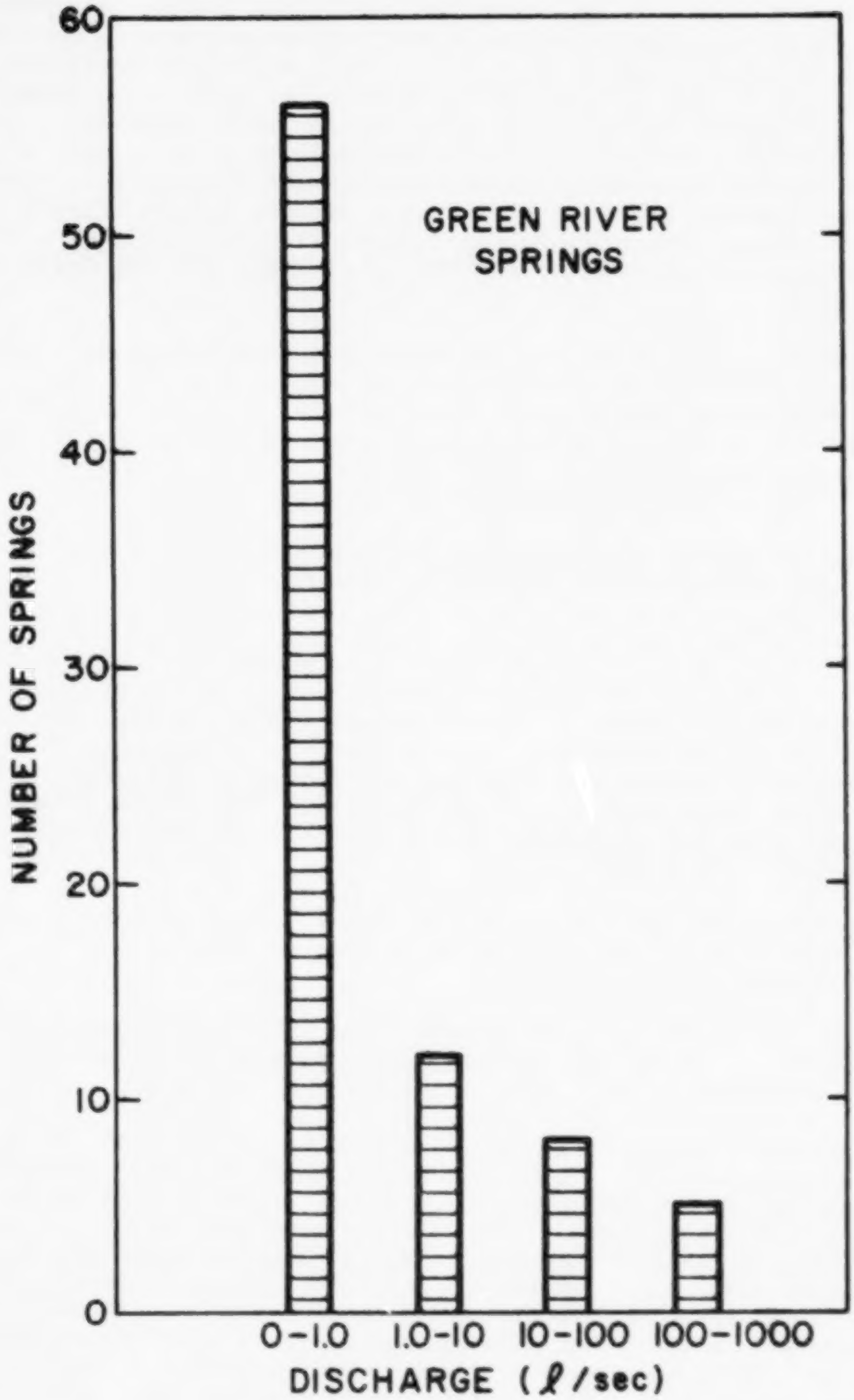


FIGURE I-10

Sub-Surface Drainage Areas

The principal aquifer in the study area is the St. Louis and Ste. Genevieve limestone. The water table in these formations is nearly flat beneath the ridges of the Chester Cuesta and occurs at the elevation of Green River, pool stage about 425 feet. At about the position of the Chester escarpment the water table begins to slope upward to the south, following generally but not exactly the dip of the formations, to meet the incoming recharge from sinking creeks at the southern margin of the Sinkhole Plain. The water table beneath the Sinkhole Plain therefore slopes to the north but is highly irregular. Evidence from a new ground water map currently being developed by J. F. Quinlan of the National Park Service shows that there are deep ground water troughs that parallel the underground drainage lines and ground water divides between adjacent ground water sub-basins. Ground water levels show extreme fluctuation during storms and rises of ground water levels in karst windows such as Mill Hole and Cedar Sink can be 50 to 100 feet.

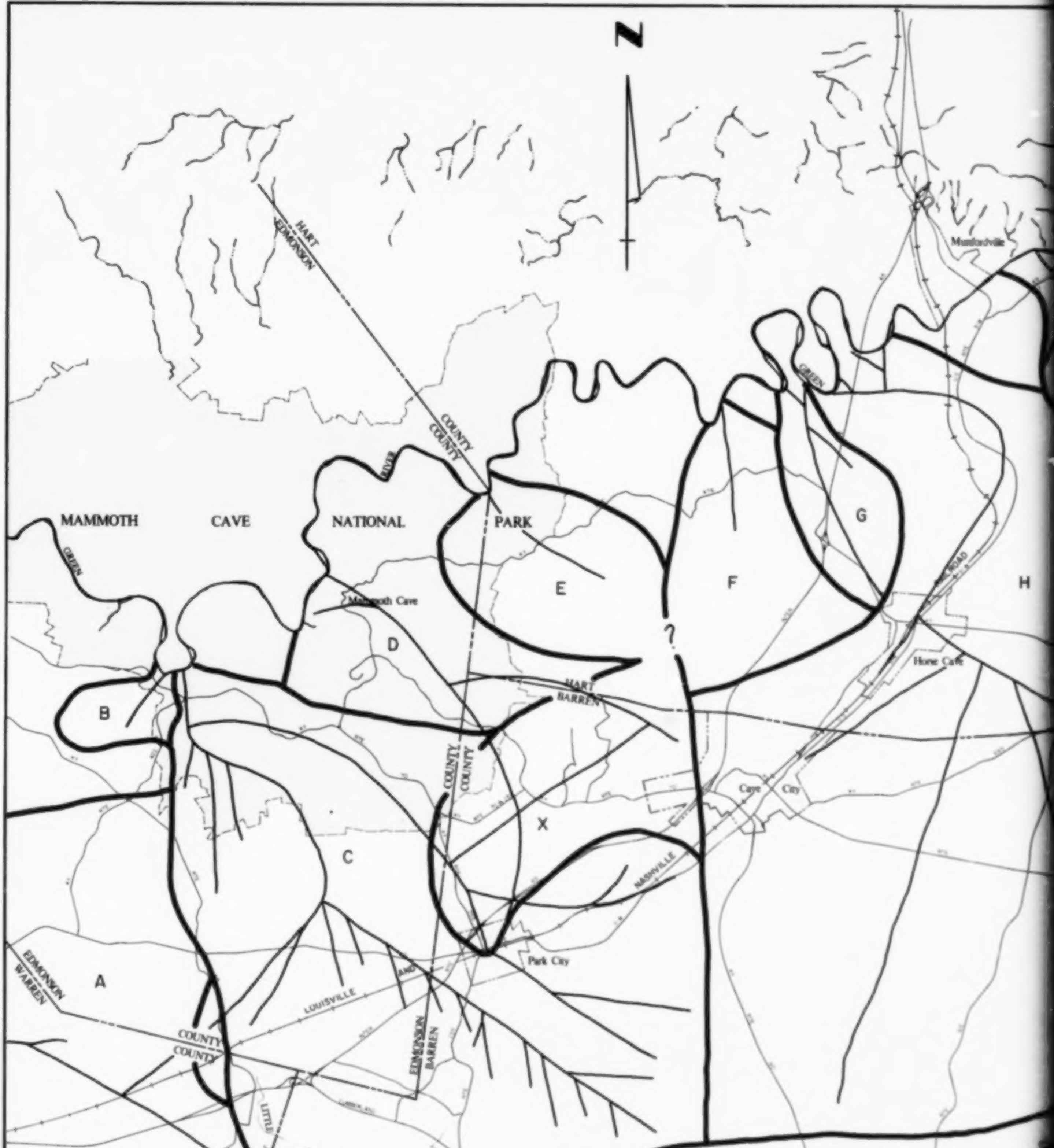
The ground water in the Mississippian limestone aquifer is divided into two components: a diffuse flow component and a conduit flow component. The diffuse flow component moves through small pores and fractures and is usually the water sampled from wells. The conduit flow component moves through open cave passages either as pipe-flow or as underground streams. Ground water in conduits drains from well-defined sub-basins with the ground water system.

It is the conduit flow component that can be traced by dyes and similar methods. The very extensive dye tracing investigations of J. F. Quinlan and his staff over the past five years has produced the drainage map shown in Figure I-11. Three of the major basins, the Graham Spring Basin, the Turnhole Spring Basin, and the Hidden River Basin are of most relevance to this study. It must be emphasized that the dye tracing experiments only establish point-to-point connections and tell nothing about the geometry of the actual cave passages that carry the water. The details of exactly where the tributaries join or the detailed path taken between the sinkholes and sinking streams where dye was injected and the caves or springs where it was detected are not known. In addition, Figure I-11 is a representation of Quinlan's map which can be seen in greater detail in his report:

> Research Report 109. Hydrology and Water Quality in the Central Kentucky Karst: Phase I, Part A, by James F. Quinlan and Dr. Donald Rowe.

In the Graham Spring Basin there are two principal tributaries which apparently join in the sub-surface near Mill Cave from which the underground flow continues to Graham Spring on the Barren River as a single master trunk.

The Turnhole Spring Basin has its headwaters in the group of springs and sinking streams south of Park City. Many of these are seen underground in Parker Cave and Gray's Water Cave where the sub-surface flows can be sampled. The Parker Cave drainage and in addition the water from Gardner Creek and Little Sinking Creek flow northward under the Sinkhole Plain and are observed again in Mill Hole, the karst fenster that extends down to stream level, and again in Cedar Sink. This one trunk drainage with no distributary system appears to be well established. The western divide between the Turnhole Spring drainage and the Graham Spring drainage is well-established by dye-tracing. It divides the group of larger sinking creeks into two sets, Sinking Creek and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HART
BARREN
COUNTY
COUNTY
Horse Cave
Cave City
RAILROAD
NASHVILLE
Park City
LOUISVILLE
AND
EDMONSON
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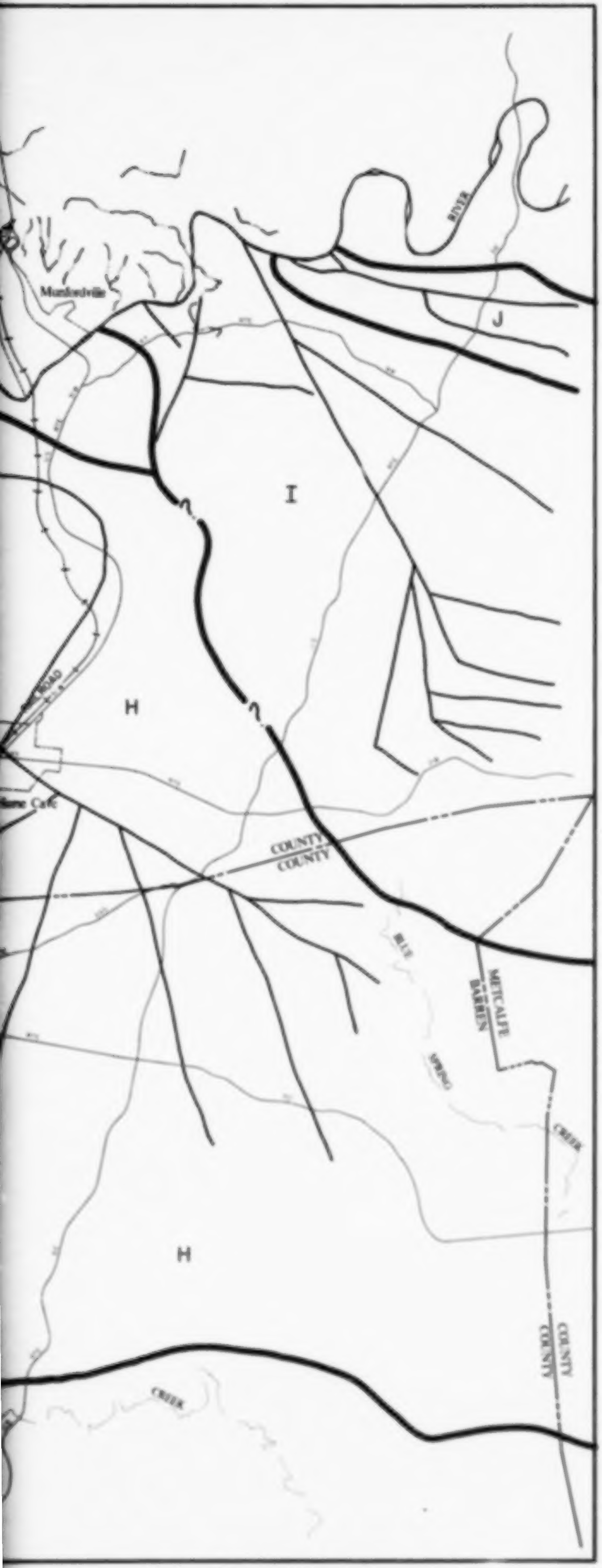
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COUNTY
CREEK

LEGEND

▨ MAMMOTH CAVE NATIONAL PARK

━ BOUNDARIES OF MAJOR GROUNDWATER BASINS

— SUBSURFACE DRAINAGE

GROUNDWATER BASINS

A. GRAHAM SPRINGS
B. DOUBLE SINKS
C. TURNHOLE SPRING
D. ECHO-STYX
E. PIKE SPRING
F. LAWLER BLUE HOLE
G. GARVIN-BEAVER
H. HIDDEN RIVER
I. THREE SPRINGS
J. GRADY SPRING
X. AREA COMMON TO BASINS C AND D

━?━ BASIN BOUNDARIES UNCERTAIN IN THIS AREA

SOURCE: JAMES F. QUINLAN

FIGURE I-11

MAMMOTH CAVE AREA
201 FACILITIES PLAN
ENVIRONMENTAL IMPACT STATEMENT

GROUNDWATER BASINS AND SUBSURFACE FLOW

12,000 6000 0 12,000 24,000
Scale in Feet

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia

B

Sinking Branch which flow west to Graham Spring and Little Sinking Creek and Gardner Creek that flow northward to the Turnhole. Madison Spring occurs directly on the drainage divide and parts of its discharge flow into both basins. The eastern and northern divides are much more complex and are not perfectly established.

The Hidden River Basin occupies most of the remaining eastern part of the study area. The headwaters are the sinking streams south of Cave City and Horse Cave and the longest surface tributary is Blue Spring Branch which flows northward across the Sinkhole Plain from the southeast. An intermediate point on this drainage line can be sampled in Hidden River Cave beneath the town of Horse Cave. Two tributaries join at the bottom of the entrance sink: the main trunk drainage from Blue Spring Branch and many of the other sinking streams, and another tributary which carries the effluent from the Horse Cave Sewage treatment plant and other local industrial wastes. The drainage line to the north is curved around the end of the remnants of the Chester Cuesta and the discharge into Green River is through some 39 springs at 14 locations over a five mile reach of the river in one of the most remarkable distributary systems yet discovered. The existence of the distribution system was predicted by J. F. Quinlan in 1974 based on the similarity in the chemistry of the spring waters particularly with respect to heavy metals. Subsequent excavations by Quinlan and his associates at the Hick Spring site provided an entrance to the Hidden River Cave Complex which allowed some of the distributary system to be mapped. Two parallel drainage systems exist to the west of the Hidden River complex. A group of sinkholes have been traced to Garvin Spring and Beaver Spring on opposite sides of a meander bend on Green River in a small distributary system (Basin G). The drainage from Crump Spring Cave has been traced to Lawler Blue Hole (Basin F).

The situation in the eastern portion of Mammoth Cave National Park is complicated and un-resolved. There are two major springs on the south side of Green River in this portion of the park: Pike Spring which discharges much of the drainage from the Flint Ridge Cave System and Echo River/Styx River (the two springs are also a distributary system) which drains Mammoth Cave Ridge. There is some question of the boundary between the Pike Spring sub-basin (E) and the Lawler Blue Hole Basin (F), between the Pike Spring drainage and the Echo/Styx basin, and between the Echo/Styx basin and the Turnhole Spring basin to the west. However, the critical question concerns the southern boundaries of these smaller basins. According to Figure I-11, they do not extend out onto the Sinkhole Plain. Base flow measurements on the Pike and Echo/Styx springs can be accounted for with only a catchment on the cavernous ridges. This would imply that the drainage from the Sinkhole Plain separates into a eastern portion that flows to the Hidden River Complex and a western portion that flows into the Turnhole Spring drainage. Quinlan draws a north-south drainage divide between Park City and Cave City which purports to separate these two major ground water basins.

Quinlan's most recent dye-tracing results in this area are quoted in the paragraphs below:

"Dye traces in the northern part of Park City show that surface runoff flows both to Echo River, within Mammoth Cave, and to Cedar Sink, thence to Turnhole Spring. The straight-line distance from Park City to these two discharge points along Green River is about the same but slightly greater to Cedar Sink. Dye appears first at Cedar Sink. The piezometric surface north of the Park City area suggests flow to the west, towards Cedar Sink and Turnhole Spring".

"Figure I-11 schematically shows the curious results of a dye test run from the I-65 interchange at Cave City, about a mile west of town. Dye traveled approximately 14 miles to Turnhole Spring via Cedar Sink -- and one to three days later also arrived at Echo River, only 8.5 miles from the interchange. The relatively small amount of dye recovered on 2 consecutive days at Echo River, when compared with the larger concentration recovered at Cedar Sink on each of 6 days over an 8-day period, strongly suggests that flow from this interchange is chiefly to Cedar Sink. Only during moderate flow and flood flow stages does water go to Echo River."

"Water in area X (Figure I-11) is known to flow both to Echo River and to Cedar Sink. The size of area X, and how its probable interditiate boundaries with five adjacent ground water basins (C, D, E, F, and H) shifts in response to rainfall and stage is not yet known. The shifting of boundaries could occur by mechanisms similar to those shown to operate in Parker Cave -- and the shifting could be different at different flood stages and in response to different rains. The mind boggles at the possible complexities -- many of which could only be understood by careful mapping of caves that one might be lucky enough to find and a series of dye tests at different flow stages."

The conclusions from dye tracing experiments, (Quinlan and Rowe, 1977, 1978; Quinlan, 1976) from water balance calculations, (Hess, 1974; Hess and White, 1974) from the chemical behavior of the ground water, (Hess, 1974; Hess and White, in press) and from the observed geometry of cave passages (Watson, 1966; Deike, 1967; White et. al., 1970) are:

(1) Most of the ground water in the Mississippian limestone aquifer is moving in well-defined systems of conduits as integrated underground streams. Although a diffuse component of the ground water must exist in fractures and pores, which supplies water drawn from wells, this water is poorly interconnected with the conduit system and represents at most 10 percent of the total water passing through the aquifer.

(2) The conduits are aggregated into well-defined underground basins. Each basin has a system of tributaries, some of which originate in sinkholes and some of which originate in sinking streams. The tributaries come together to form master trunk streams which carry water towards the rivers.

(3) Only the Turnhole Spring Basin has its discharge at a single discrete spring. All others have distributary systems in the downstream sections of the trunk so that water from the underground basins appears at more than one spring. Thus it is not possible to say that pollutants introduced at some specific cave or sinkhole will emerge from a specific spring. Point source pollutants will in all liklihood be distributed over much of the sub-basin in which the point source occurs and could contaminate a number of springs and underground streams.

(4) Some point sources appear to drain into more than one sub-basin. Such divergent flow has been found dominantly

in the Park City - Cave City area where the injected dye appeared in both Turnhole Spring and in Echo River Spring.

(5) The boundaries of the sub-basins are not fixed. They move in unknown ways depending on ground water levels in the aquifer and on the flood stage of the surface rivers. This is caused by filling of normally dry cave passages which may spill over into adjacent basins. This effect is particularly important with respect to Echo River Spring. Under low flow conditions Echo River Spring derives its water almost entirely from the region of Mammoth Cave Ridge and much of its catchment is within the National Park. Under high flow conditions, a spillover appears to occur at an unknown point and water from the Park City - Cave City area of the Sinkhole Plain flows under the ridges to greatly augment the flow of Echo River Spring. This would imply that pollutants introduced in the more highly populated part of the Central Kentucky Karst could be carried into the National Park, affecting aquatic life in the low level passages and even reaching portions of the cave close to those used by visitors.

Water Balance

Some indication of the behavior of ground water in the principal carbonate aquifer can be obtained by water balance criteria. By making use of the effective drainage area between the Green River gage at Brownsville and the gage at Munfordville it is possible to use long term U.S. Geological Survey stream records to determine water balance. The only major tributary to enter Green River in this reach is the Nolin River which itself is gaged and therefore can be deducted. The drainage area between the gages less the Nolin catchment is 382 mi^2. Green River bisects this catchment into two parts, 95 mi^2 north of the river and 287 mi^2 south of the river. The water balance was carried out for the entire area by Hess (1974) and Hess and White (1974), (Table I-8). The following tables summarize their results.

TABLE I-8 BASIN DISCHARGE DATE

	Area		Mean Annual Discharge		Normalized Mean Runoff		Years of Record
	km^2	mi^2	1/sec	CFS	$1/sec/km^2$	CSM	
Green River Basin above Brownsville	7154	2762	115,149	4066	16.1	1.47	40
Green River Basin above Munfordville	4333	1673	72,640	2565	16.8	1.53	45
Nolin River	1831	707	23,222	820	12.7	1.16	23
Central Kentucky Karst	989	382	19,286	681	19.5	1.78	--

Long term precipitation data were obtained from 34 years of record at Mammoth Cave National Park and 9 years of record at Bowling Green. The mean average precipitation is 49.77 inches (1264 mm). Evaporation-transpiration losses were estimated by three methods using the mean annual temperature of the region:

Class A pan	39.9 inches	1014 mm
Lake	37.0	940
Thornthwaite Potential	30.2	767

These can be compared with E-T losses estimated from river records using a simple balance argument. By subtracting the measured runoff from the precipitation, the evaporation-transpiration is obtained (Table I-9).

TABLE I-9 RUNOFF AND EVAPO-TRANSPIRATION LOSSES

Basin	Runoff		Evapo-Transpiration	
	inches	mm	inches	mm
Green River at Brownsville	19.99	508	29.76	756
Green River at Munfordville	20.83	529	28.94	735
Nolin River Basin	15.75	400	34.02	864
Central Kentucky Karst	24.20	615	25.55	649

The evapor-transpiration loss for the entire Green River basin calculated at both gaging stations agrees rather well with the estimate from the Thornthwaite potential.

The base flow runoff from the karst area can be obtained by a similar technique. The average monthly low flows at Nolin and Munfordville gages were deducted from the monthly flow at Brownsville and the residual assigned to the low flow runoff from the study area. The values obtained were 55.9 cfs (1580 liter/sec) after a correction for evaporation loss from the river itself. The specific base flow runoff for the karst area is then calculated to be 0.15 cfs/mi^2 (1.64 liter/sec/km^2).

The river runoff can be compared with the spring runoff. Of the 81 springs identified along Green River between the gages, the 9 largest account for 95% of the spring discharge. The two largest springs draining from the south, Gorin Mill Spring and Turnhole Spring together account for 56% of the total spring discharge and an even larger fraction of the drainage from the area south of Green River. The six largest springs that enter Green River from the south were measured at various times and a total base flow discharge of the spring group was estimated to be 66 cfs. This yields a value of 0.17 cfs/mi^2 (1.86 liter/sec/km^2) as the specific base flow runoff, a number that is actually larger than the value obtained from the river records (0.15 cfs/mi^2). The conclusion is that to within experimental error, all discharge from the karst area is through conduit systems draining to big springs. The diffuse flow component, which in principle must exist, is lost in the experimental uncertainties. Since there is no surface flow to Green River, the internal runoff through the karst aquifer represents the entire groundwater resource. Decisions concerning the management of the underground waters, and of the influence of introduced pollutants must take account of the conduit system.

Groundwater Quality Criteria

Presently, the Commonwealth of Kentucky does not have specific groundwater quality criteria. Existing groundwater standards are based on maintaining a quality of groundwater consistent with its designated use. In addition, an anti-degradation policy provides for the protection of groundwater which would "be significantly degraded in quality" before exceeding standards for designated use. However, for free-flowing groundwaters which have a demonstrable nexus to surface streams, the standards are more specific. The Kentucky Division of Water Quality and EPA apply Kentucky Water Quality Standards, as established in 40 CFR 120.21, which provide in Section 1.(2) of Regulation WP-6-2,[1] that these waters be classified Aquatic Life and shall meet the water quality criteria supporting that classification and, in addition, shall meet the criteria necessary to support contact recreation.

More than 90% of the groundwater discharge in the Mississipian limestone aquifer in the study area is free-flowing and moves in well defined systems of conduits as integrated underground streams (as described in the previous section). These conduits are aggregated into discrete subsurface drainage basins, each basin having a system of tributaries (from sinkholes or sinking streams) which join together forming master trunk streams which carry water towards the rivers. Since these systems have a demonstrable hydrologic nexus to the surface waters (Green River), the Aquatic Life classification may presently be applied to all these subsurface waters.

Water quality in these subsurface waters is the subject of a groundwater study, the results of which are incorporated into this impact statement. The main objectives of the groundwater study are to 1) assess the applicability of the EPA Aquatic Life classification to all free-flowing groundwaters in the Mammoth Cave study area; and 2) develop any necessary additional (or alternative) water quality goals for subsurface waters in the Mammoth Cave area. Because of the unique groundwater system in this karst area, any goals developed should not apply generally to the groundwaters of the Commonwealth of Kentucky.

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[1] Section 1.(2) Regulation WP-6-2: All Waters as defined in 40 CFR 125.1 not shown on the map described in (1) of this section shall be classified Aquatic Life as set forth in (Section 6 of 401 KAR 5:025) and shall meet the water quality criteria supporting that classification, and in addition shall meet the following criteria necessary to support secondary contact recreation as being: Fecal coliform shall not exceed an average of 2000/100 ml and not exceed a maximum of 4000/100 ml.

Existing Water Quality Data

To assess the applicability of the Aquatic Life classification or to develop groundwater goals, it is necessary to obtain the following types of information concerning the subsurface waters in the Mammoth Cave area: (1) Drainage patterns; (2) quantity of flows; (3) natural water quality of subsurface streams and of sinking streams that flow into the groundwater system; (4) water quality of subsurface streams receiving wastewater discharges; and (5) sensitivity of aquatic biota to waste discharges. The most extensive data on groundwater in the study area are contained in published reports by James F. Quinlan and Donald R. Rowe, Ph.D., Hydrology and Water Quality in the Central Kentucky Karst Phase II Part A. These reports provide detailed information on the drainage patterns of the subsurface streams in the study area as well as estimates of discharge volumes during "base flow" conditions. (Quinlan and Rowe's work on subsurface drainage basins is summarized under Sub-Surface Drainage Areas in Section 9 of this inventory.)

In addition, Phase I includes results from intensive water quality sampling (during both moderate and base flow conditions) in the following groundwater basins:

1) Hidden River
2) Grady Springs
3) Three Springs
4) Garvin-Beaver
5) Lawler-Blue Hole

One of the primary functions of the Quinlan-Rowe sampling program was to trace the extent of heavy metals pollution in the Hidden River basin due to the effluent discharge from the Horse Cave wastewater treatment plant and to compare levels of heavy metals and other inorganic constituents at the Hidden River effluent-bearing springs along the Green River with springs from adjacent groundwater basins. The results of these chemical analyses and the comparisons appear in Tables I-10 and I-11 respectively.

These data indicate that the Hidden River Cave South Branch is heavily polluted with respect to toxic heavy metals due to the effluent discharge of the Horse Cave wastewater treatment facility and that the East Branch of Hidden River Cave is relatively unpolluted with heavy metals. In addition, results from analyses of the Hidden River effluent-bearing springs indicate that, even under base flow conditions, sufficient dilution is available in the Hidden River system to reduce concentrations of heavy metals at the springs to within drinking water standards. However, as mentioned in the report, drinking water standards may not protect some forms of aquatic life. Furthermore, different heavy metals concentrations in the effluent bearing springs ranged from 1.9 (zinc) to 5.1 (nickel) times greater than springs in adjacent groundwater basins. These adjacent basins, Grady Spring, Three Springs, Garvin-Beaver and Lawler Blue Hole are considered to be representative of unpolluted (with respect to heavy metals), free-flowing groundwaters in the area.

In addition to data on free-flowing groundwaters, the Quinlan-Rowe report also provides water quality data on diffuse-flow groundwaters in the Hidden River Basin. The report concludes that these diffuse-flow groundwaters, which are generally used for domestic water supplies, appear to be independent of the conduit flow system in the caves and springs.

Although the Quinlan-Rowe data provide documentation for heavy metals pollution in the Hidden River complex as well as some information regarding natural water quality in adjacent unpolluted (with respect to heavy metals) groundwater basins, the data is only of limited use in assessing the applicability of the Aquatic Life classification to all subsurface waters in the area or developing groundwater standards, for the following reasons:

1) Sampling sites in the groundwater basins adjacent to the Hidden River Basin were confined to the springs along the Green River. Local pollution problems upstream in the drainage areas may not be detected because of dilution.

2) With the exception of some bacteriological tests, water quality analyses were only performed for heavy metals and other inorganic parameters. These included chromium, nickel, copper, zinc, chloride, sodium, patassium, carbonate hardness, calcium, magnesium and specific conductance. Evidences of pollution resulting from human or animal waste are not usually detected with analyses for these parameters.

Field Sampling Program

A field sampling program was conducted as part of this impact statement to expand on the Quinlan-Rowe data base and to provide the following types of information:

- Natural water quality of subsurface streams and of sinking streams that flow into the groundwater system.
- Water quality of subsurface streams receiving wastewater discharges.
- Identification of sources of groundwater pollution.

This field sampling program included analyses for not only the heavy metals and other inorganic parameters but for water quality parameters specifically associated with human and animal wastes as well as agricultural activities.

These additional water quality parameters include the following:

- Biochemical Oxygen Demand (BOD)
- Dissolved Oxygen (DO)
- Synthetic Detergents (MBAS)
- Total Kjeldahl Nitrogen (TKN)
- Ammonia Nitrogen (NH_3-N)
- Nitrate Nitrogen (NO_3-N)
- Total Coliform
- Fecal Coliform
- Fecal Streptococcus
- Pesticides
- Ortho Phosphate
- Total Phosphorus

Because there are such a large number of subsurface streams and tributaries, and since most are inaccessible, it is far beyond the scope of this project to sample and analyze water quality of every subsurface stream. The sampling program was designed to obtain water quality data from selected sampling sites which would be useful in making some general conclusions about subsurface water quality in the area. For example, one objective of the study was to monitor water quality in a "typical" drainage basin as water flows from headwaters, to surface streams, to subsurface drainage under the sinkhole plain and then into the Green River. For this purpose, several sites in the Turnhole Spring drainage basin were sampled to detect changes, if any, in water quality as the groundwater is subjected to contamination from subsurface wastewater discharges, runoff from agricultural areas or other pollution sources such as abandoned oil wells. Several sampling sites were also selected in the Hidden River basin because other objectives of the study were to monitor water quality data upstream and downstream of the known subsurface wastewater discharges of Horse Cave and Cave City and to monitor the effluents at each plant.

The sampling program was conducted in two phases, the first phase during moderate flow conditions (March 1978) and the second during base flow conditions (September-November 1978). During both moderate and base flow conditions one-time grab samples were collected at each sampling location. However, since base flow conditions are generally much more critical for maintaining water quality, an extended sampling program was conducted to expand the limited data generated by a one-time grab sample. Samples were collected each week (for a period of 10 weeks) at seven strategic sampling sites. These sites were selected after consultation with the Groundwater Technical Assistance Committee associated with this study and are noted with the site descriptions which follow. During this sampling program analyses were performed for the following parameters:

1) Dissolved Oxygen (1/week)
2) Nitrate, Ammonia and Total Kjeldahl Nitrogen (1/2 weeks)
3) Conductivity (1/week)
4) Temperature (1/week)
5) Heavy Metals (Hidden River Basin sites only) (1/week)

Site Descriptions

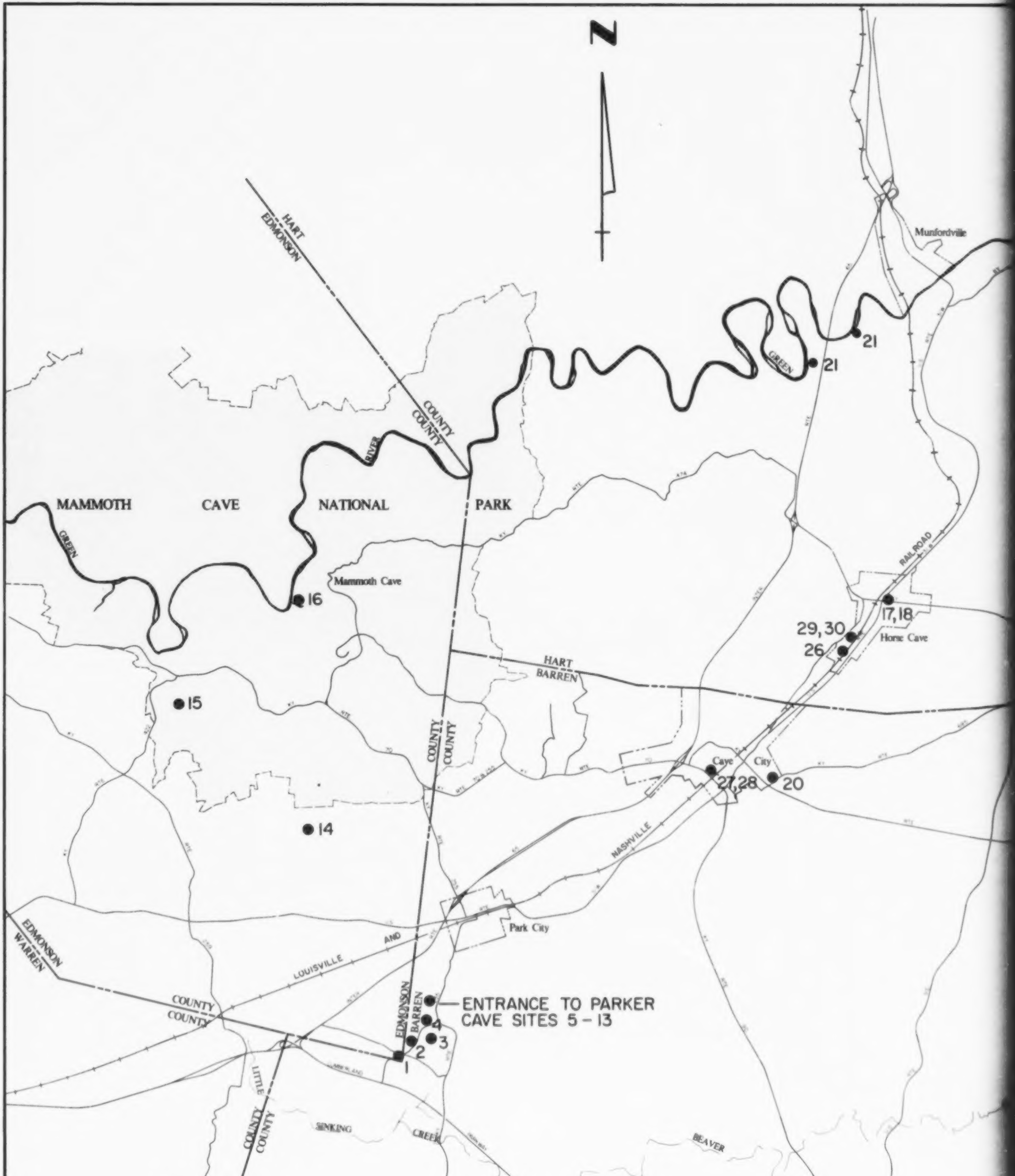
The locations of all the sampling sites are indicated in Figures I-12 and I-13. A total of twenty-six sampling stations (1-21 and 26-30) were selected for the program. Sampling stations 1-15 are located at various points in the Turnhole Spring basin from the headwaters area to Cedar Sink. Sampling station 16 situated at the Echo River Spring of the Echo-Styx Basin. Sampling stations 16-21 are located at different points in the Hidden River basin, while stations 26-30 are found at the major wastewater sources in the Hidden River Basin (Ken Dec, Inc., Horse Cave wastewater treatment plant and Cave City wastewater treatment plant). Descriptions of the sites and rationales for site selections are as follows:

Turnhold Spring Drainage Basin

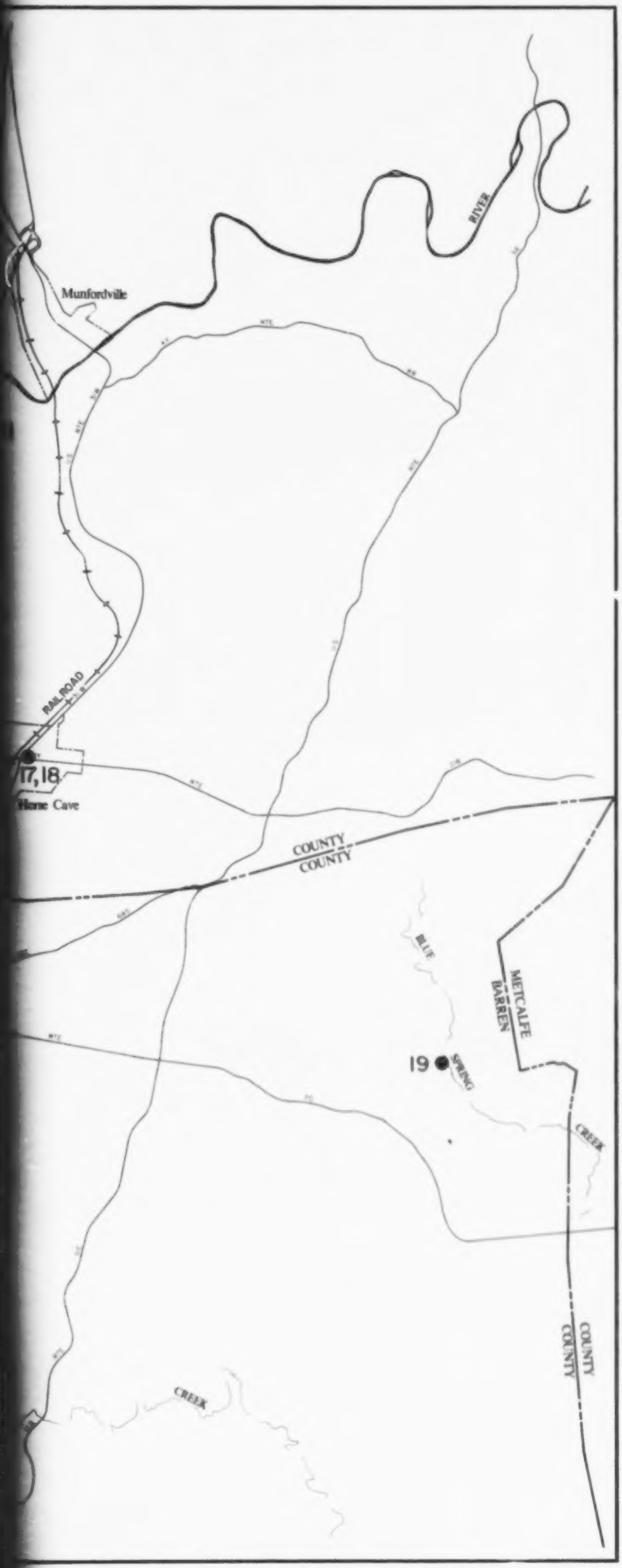
#1 Glasgow Upland

Sampling station #1 is located in a bog area in the Glasgow Upland at a drainage divide between the Barren River and Green River basins. In the Glasgow Upland, there are many small swamp areas that feed perennial springs. These springs then feed surface streams that flow toward the Green River and then sink at the sink hole plain entering the subsurface conduit systems.

This sampling site was selected to provide background or natural water quality, since waters in this area are considered to be representative of headwaters to the drainage basins in the "pristine state". This particular sampling site is a source of water for the Parker River system.


N
HART
EDMONSON
COUNTY
COUNTY
Munfordville
GREEN
RIVER
21
21
MAMMOTH
CAVE
NATIONAL
PARK
GREEN
Mammoth Cave
16
RAILROAD
17,18
29,30
26
Horse Cave
HART
BARREN
15
COUNTY
COUNTY
Cave
City
27,28
20
14
NASHVILLE
Park City
EDMONSON
WARREN
LOUISVILLE
AND
COUNTY
COUNTY
EDMONSON
BARREN
ENTRANCE TO PARKER
CAVE SITES 5 - 13
4
3
2
1
LITTLE
COUNTY
COUNTY
SINKING
CREEK
BEAVER
WARREN
BARREN

A


RIVER
Munfordville
RAILROAD
17,18
Horse Cave
COUNTY
COUNTY
BLUE
METCALFE
BARREN
19
SPRING
CREEK
COUNTY
COUNTY
CREEK

LEGEND

▨ MAMMOTH CAVE NATIONAL PARK

● SAMPLING SITE LOCATION

1. GLASGOW UPLAND
2. GUILFOIL SPRING
3. LOCAL HOGLOT DRAINAGE
4. APPLE - GROVE GUILFOIL SPRING STREAM *

5-13. PARKER CAVE STATIONS

14. MILL HOLE *
15. CEDAR SINK (MAR. SAMPLE) OWL CAVE (OCT. SAMPLE)
16. ECHO RIVER
17. SOUTH BRANCH HIDDEN RIVER *
18. EAST BRANCH HIDDEN RIVER *
19. BLUE SPRING BRANCH *
20. L & N CAVE *
21. HICK'S SPRING (MAR. SAMPLE) GORIN MILLS (OCT. SAMPLE)
26. KEN - DEC MANHOLE
27. INF. CAVE CITY STP
28. EFF. CAVE CITY STP
29. INF. HORSE CAVE STP
30. EFF. HORSE CAVE STP *

* LONG-TERM SAMPLING SITE.

FIGURE I -12

MAMMOTH CAVE AREA
201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

SAMPLING STATION LOCATIONS

12,000 6000 0 12,000 24,000
Scale In Feet

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia

B

#2 Guilfoil Spring

Sampling station #2 is located in a surface stream that originates near Apple Grove and flows through pasture land. Samples were collected just downstream from the confluence of this stream and waters flowing from Guilfoil Spring, a perennial spring that furnishes water to several families in the area. (During base flow conditions samples were also collected just upstream from the spring.)

The sampling site was selected to monitor the effects of the Apple Grove population and the local agricultural activity on the water quality of the streams after flowing only a few thousand feet from the recharge area.

#3 Local Drainage

Sampling station #3 is located in an intermittent surface stream at a point upstream from its confluence with the Apple Grove-Guilfoil Spring stream.

This station was selected because the headwaters of this small stream are located in a hog lot. Samples were taken at the site to determine the extent of local pollution resulting from runoff from the hog lot and to provide an indication of the waste load contributed by this type of agricultural activity.

#4 Apple Grove-Guilfoil Spring Stream

Sampling station #4 is located in the Apple Grove-Guilfoil Spring stream downstream of its confluence with the drainage from a hog lot that supports approximately 75 hogs. The site was selected to determine the effects of the hog lot drainage on water quality. In addition, the site is the last point where the stream may be sampled before it flows through some pasture land and sinks to join Parker River, a major subsurface stream in Parker Cave. For this reason, the site was also selected for the long-term sampling program.

#5 Parker River

Sampling station #5 is located in Parker River about 300 feet from the entrance of Parker Cave. The point of sampling is upstream from where Parker River is joined by the Apple Grove waters sampled at stations 1-4.

The site was selected to provide background water quality of Parker River before being joined by the Apple Grove stream.

#6 Parker River

Sampling station #6 is located in Parker River downstream from its confluence with the Apple Grove area drainage. The site was selected to monitor changes in water quality in Parker River after being combined with the sinking stream.

#7 Parker River

Sampling station #7 is located in Parker River immediately downstream from a point where a spring of high sulfate content enters Parker Cave.

It is suspected that many of the abandoned oil wells in the sink hole plain may be leaking brines high in chlorides and sulfates. This site was selected to provide data on the effects of this "sulfur spring" on the water quality of Parker River. More generally, this sample provides information regarding this type of non-point pollution which can degrade subsurface waters.

#8 Brown River

Sampling station #8 is located in Brown River, a large subsurface stream which is accessible in Parker Cave. The Brown River is an integrated stream resulting from approximately 10 surface streams which drain a substantial area of the sink hole plain, base flow being approximately 2.5 cfs. Downstream from the sampling site, it combines with Parker River and other subsurface streams before reaching Mill Hole.

The Brown River sampling site was selected to provide water quality data representative of subsurface waters receiving large quantities of agricultural runoff. In turn, these data provide at least a limited basis for assessing the impacts of agricultural activity on subsurface water quality.

#9 Parker River

Sampling station #9 is located in Parker River at the last accessible point before it flows to Mill Hole. The site was selected to provide water quality downstream in Parker River after receiving all the small tributary flows which enter during its passage through Parker Cave.

#10 Subsurface drainage

Sampling station #10 is located in Parker Cave, at a point where subsurface "runoff" from a small area of the sinkhole plain enters the cave. Since no surface streams flow directly to this point, the water probably moves slowly from the surface through the soil and rock formations to the cave.

Samples taken at this site provide an indication of local water quality and of any changes in water quality as water "percolates" through sinkholes into the cave system.

#11 Sulfur River

Sample station #11 is located in Sulfur River in Parker Cave immediately downstream from the Phantom Sulfur Spring. As at station #7, this station was selected to indicate water pollution problems associated with subsurface sources of chlorides and sulfates.

#12 Phantom Sulfur Spring

The Phantom Sulfur Spring in Parker River Cave is a subsurface source of sulfate, hydrogen sulfide and chloride pollution, apparently caused by leaking brine from an abandoned oil well. The spring was sampled to determine the concentrations of these pollutants.

#13 Sulfur River upstream of the Phantom Spring was not sampled.

#14 Mill Hole

Sample station #14 is located in Mill Hole, a large karst window in the Cedar Sink Valley. Water from Brown River, Parker River and other subsurface streams in the Turnhole Spring basin combine to form a large trunk stream which flows toward the Green River. The stream is accessible at Mill Hole.

This sampling station is important because it provides a composite water quality sample from all the subsurface streams in the southwestern portion of the Turnhole Spring basin. Therefore, it was also included in the long-term sampling program.

#15 Cedar Sink - Owl Cave

The Mill Hole trunk stream and Patoka Trunk, the other major trunk stream in the Turnhole Spring basin have their confluence just upstream from Cedar Sink. (Cedar Sink is located in Mammoth Cave National Park.) During moderate to high flow conditions this combined flow is accessible in the bottom of Cedar Sink but during base flow conditions only in Owl Cave. Therefore, moderate flow samples were collected in Cedar Sink while base flow samples were taken in Owl Cave near the entrance.

The Cedar Sink sampling site is considered important because the Patoka Trunk stream drains the Park City area where most residents discharge domestic wastewaters directly to the subsurface streams via crevices in the rock. It is the only known point to detect any pollution problems resulting from the Park City discharges.

Echo-Styx Basin

#16 Echo River

Sampling station #16 is located at Echo River Spring where waters from the Echo River system in Mammoth Cave National Park "boil" to the surface and flow to the Green River.

The purpose of sampling Echo River was to determine water quality characteristics and detect any pollution problems in the National Park stream since groundwater tracing has indicated that at least during high flows, some drainage from the Park City area flows to the Echo-Styx Basin.

Hidden River Basin

#17 South Branch of Hidden River Cave

Sampling site #17 is located in the South Branch of Hidden River Cave at the entrance in downtown Horse Cave. The sampling point is approximately one (1) mile downstream from the Horse Cave wastewater treatment plant discharge. Samples were collected at this point to indicate the magnitude of the pollution problems caused by the Horse Cave treatment plant effluent. Because of the severity of the pollution problem, this site was included in the long-term sampling program.

#18 East Branch of Hidden River Cave

Sampling station #18 is located in the East Branch of Hidden River Cave near the main entrance to the Cave and immediately upstream from its confluence with the South Branch. The East Branch of Hidden River Cave is a major trunk stream that drains a large area of the sinkhole plain south and east of Horse Cave, the largest contributing sinking stream being Blue Spring Branch (Sampling Station 19). In addition, recent dye tracings by Dr. James Quinlan (personal communication) indicate that the effluent from the Cave City wastewater treatment plant also flows to the East Branch. This sampling site is especially important because it provides access to monitor water quality "downstream" from the Cave City wastewater treatment facility in addition to providing a composite sample from a large drainage area on the sinkhole plain. Therefore, it was included in the long-term sampling program.

#19 Blue Spring Branch

Sampling station #19 is located in Blue Spring Branch near Hiseville, Kentucky. Blue Spring Branch is the largest surface tributary to the East Branch of Hidden River Cave. The sampling station was selected to provide an "upstream" sample of the water entering the East Branch of Hidden River Cave. Water quality at this point may be compared to that of sampling station 18 to note changes that are possibly due to the effects of the Cave City wastewater discharge. For this reason, it was also included in the long-term sampling program.

#20 L & N Cave

Sampling station #20 is located at the entrance of L & N Cave in Cave City, Kentucky. This site provides a sample of waters flowing to the East Branch of Hidden River Cave upstream from the Cave City wastewater treatment plant discharge. This site was also included in the long-term sampling program.

#21 Hick Spring - Gorin Mill Spring

Waters from the Hidden River Cave complex surface in a series of springs along the Green River, two of which are Hick Spring and Gorin Mill Spring. Hick Spring was sampled during the moderate flow sampling, but because Hick Spring is contaminated by oil well brines during base flow conditions, station 21 was moved to Gorin Mill Spring. Both sites provide a point to sample downstream from the confluence of East and South Branches of Hidden River Cave to monitor the effects of the effluent discharges on water quality after dilution. After the base flow sampling revealed low dissolved oxygen levels in Gorin Mill Spring, this site was included in the long-term sampling program.

#26 Ken Dec, Inc.

Sampling station #26 is located at the Ken Dec discharge to the Horse Cave sewerage system. Samples were collected to monitor metals concentrations being discharged to the Horse Cave wastewater treatment plant.

#27 and #28 Cave City Wastewater Treatment Plant

Samples of the influent (#27) and effluent (#28) at the Cave City wastewater treatment plant were collected at stations 27 and 28 respectively.

#29 and #30 Horse Cave Wastewater Treatment Plant

Samples of the influent (#29) and effluent (#30) at the Horse Cave wastewater treatment plant were collected at stations 29 and 30 respectively. Because of past pollution problems, heavy metals analyses of the effluent were performed during long-term sampling.

Water Quality Parameters

The water quality parameters sampled in the field studies program include those which have general application in assessing water quality and some which have specific application to water quality problems in the Mammoth Cave study area. These parameters are listed and described below.

Dissolved Oxygen

Determination of dissolved oxygen is one of the most important water quality tests. Maintaining adequate levels of dissolved oxygen is necessary for the protection of the aesthetic qualities of water as well as for the protection of fish and other aquatic life. Insufficient dissolved oxygen causes anaerobic decomposition of organic materials and this forms noxious gases such as hydrogen sulfide. Dissolved oxygen levels less than 5 mg/l are detrimental to some aquatic life. High concentrations of dissolved oxygen indicate a low amount of biologically available organics.

Biochemical Oxygen Demand (BOD)

BOD is usually defined as the amount of oxygen required by bacteria to decompose bio-degradable organic matter under aerobic conditions. The BOD test is used to determine the pollutional strength of wastes in terms of the oxygen that these wastes will require if discharged into a watercourse in which aerobic conditions exist. BOD data indicate the degree of pollution in streams and the test is of importance in evaluating the purification capacity of a water body.

Nitrogen

Analyses for nitrogen in its various forms is one method of assessing water quality and detecting pollution. When organic wastes containing nitrogen are introduced to an aquatic environment, bacteria begin to convert this organic nitrogen to ammonia nitrogen. Under aerobic conditions, as time progresses, oxidation of ammonia to nitrites and then nitrates occurs. Nitrites, however, only represent a very small part of the total nitrogen present since they are converted to nitrates very rapidly. They are, therefore, of limited significance to water quality analyses. Based upon knowledge of these biochemical reactions, data from nitrogen analyses can be interpreted. Nitrogen concentrations of mostly organic and ammonia nitrogen (Organic-N + Ammonia-N = Total Kjeldahl Nitrogen) generally indicate that the water has recently been subjected to pollution. The presence of nitrate nitrogen indicates that the waters may have been polluted a long time previously. However, agricultural runoff contains nitrates leached from the fertilizers in the soil or from stabilized animal wastes and provides a direct source of nitrates. Nitrates are of sanitary significance since high nitrate nitrogen concentrations (>10 mg/l) often cause methemoglobinemia in infants.

Total Coliform, Fecal Coliform, Fecal Streptococci and FC/FS Ratio

Bacteria of the coliform group are considered the primary indicators of fecal contamination and are some of the most frequently applied indicators of water quality. Total coliform bacteria have been associated with feces of warmblooded animals and with soil. The fecal coliform bacteria, because they are restricted to the intestinal tract of warmblooded animals, are useful indicators of fecal pollution and therefore used as an indicator of water quality. The analyses performed for this study were done by milipore filters and the results are expressed as No/100 ml.

The ratio of fecal coliform densities to fecal streptococci densities can be useful in identifying the source of the pollution, either as human or other animals (Geldreich, 1976). Untreated municipal sewage usually reveals a ratio of 4.0 or greater. Ratios greater than 1 usually indicate that the source of pollution is from man. Ratios less than 0.6 are indicative of pollution from other animals such as livestock, poultry, cats, dogs, and wildlife. However, there are many restrictions and limitations to interpretations of the ratios as listed below:

1. The ratio is of limited value if there are less than 100 organisms/l of fecal streptococci.
2. Many samples per site should be taken and averaged before a ratio may be interpreted. (GFC&C presents ratios that result from only 1 sample and consequently are of only limited value).
3. Milk, cheese and other creamery wastes cause a decrease in the ratio.
4. Survival time of the bacteria differ so that samples should be taken at the point of discharge or within a limited distance downstream from the source of pollution.
5. Heavy metals cause changes in the survival of organisms and ratios are variable.
6. Fecal streptococci bacteria are stressed by exposure to chlorine in sewage effluents and this may cause an increase in the ratio.

Other limitations to the interpretations exist, but the above listed limitations are of importance to the interpretation of the ratios resulting from the grab samples by GFC&C.

Heavy Metals

Heavy metals such as copper, zinc, lead, chromium and nickel can be toxic to aquatic life as well as to humans. In natural waters they are usually present in only trace amounts. Analyses for metals are especially important in waters in the Hidden River Cave System because of the large quantities of these heavy metals discharged by the Horse Cave wastewater treatment plant.

Conductivity

The conductivity of a solution is a measure of its ability to conduct an electrical current. This is dependent on the number and types of ions present in the solution. The conductivity test provides a rough indicator of dissolved solid levels and is especially valuable in the differentiation of water sources.

pH

pH expresses the intensity of the acid or alkaline condition of a solution. The toxicity of some compounds to fish is changed by the pH. For example, ammonia is 10 times more toxic at pH 8.0 as at pH 7.0; cyanide toxicity to fish increases as pH is lowered. Consequently, it is important to know the effect of pH on toxicity of different compounds when assessing their effect on water quality. In addition, pH extremes alone are also toxic to aquatic life.

Hardness

Hardness concentrations have not been proven health related, but toxicity of heavy metals to fish may be related to hardness. Often times, heavy metals are less toxic to fish in hard water than in saft waters.

Solids (Total Dissolved and Total Suspended)

Excess dissolved solids are objectionable in drinking water because of physiological effects (laxative) and unpalatable tastes. Suspended solids in water interfere with aesthetics and recreational uses. Suspended solids can cause death to fish, reduce their growth rate and resistance to disease and prevent successful development of eggs and larvae.

Both dissolved solids and suspended solids can be used as an indicator of pollution problems.

Chlorides and Sulfates

Chlorides in reasonable concentrations are not harmful to humans. Concentrations higher than 250 mg/l impart a salty taste which is objectionable to some people. However, in some areas of the world water supplies contain up to 2,000 mg/l, and there are no adverse health affects once the human system has adapted. Sulfates are indirectly responsible for odor and corrosion problems. In the absence of dissolved oxygen and nitrates, sulfates act as a source of "oxygen" for biochemical oxidations by bacteria. When pH is less than 8.0, hydrogen sulfide is produced as a by-product and causes odor problems. Concentrations of chlorides and sulfates are useful in this study because presence of these substances indicates possible contamination from oil wells in the area.

Phosphorus and Phosphates

Phosphorus in the elemental form is particularly toxic and is subject to bioaccumulation. Phosphorus as phosphate is one of the major nutrients required for plant nutrition and is essential for life. Provided other essential plant nutrients are available, excess phosphates can lead to eutrophication.

Phosphates enter waterways from different sources; for example, human and animal wastes, phosphate detergents, fertilizers, and feedlots. Phosphorus data are useful in assessing the potential biological activity of surface waters and in determining the amount of phosphate that can be discharged to a stream.

Methylene Blue Active Substances (MBS)

Methylene blue active substances indicate the presence of soaps, detergents and other surfactants in the water. In abundance, these substances indicate pollution from domestic wastewaters. The Kentucky Water Quality standards permit MBAS concentration of 0.5 mg/l in drinking water.

Results and Discussion

As previously stated, the sampling program was conducted in two phases, the first phase during moderate flow conditions and the second during base flow conditions. Sampling was performed under both flow conditions for the purposes of comparison of water quality and to indicate any pollution problems peculiar to each flow condition. During moderate or high flow conditions the large volumes of water in the streams provide dilution and minimize the effects of some pollutants. However, during these higher flow periods rainfall runoff may transport other pollutants (especially from agricultural activities) to the groundwaters. During base flow conditions the small stream flows provide little dilution and pollution sources are generally detected more easily. These flow conditions are considered most critical for maintaining water quality, especially with respect to dissolved oxygen (D.O.) levels.

Based on the water quality analyses results from both moderate and base flow sampling, it appears that, with the exception of the polluted waters in the Hidden River Cave System, the water quality of the sinking streams and subsurface waters in the study area is generally good to excellent, sufficient for maintaining aquatic life. The aquatic life water quality criteria are defined by the EPA Quality Criteria for Water, EPA, Washington, D.C., July 1976. EPA criteria for selected water quality parameters for the use classifications of aquatic life, bathing water and public water supply are presented in Table I-12. Kentucky Water quality standards for aquatic life and public drinking water are presented in Appendix I.

A discussion of the field sampling results is presented in this section in two parts. The first part deals with the results of the one-time grab samples collected during moderate flow and base flow conditions. Results from this sampling program provide a picture of water quality at only one point in time during each of the flow conditions. In the second part, the results of the base flow extended sampling program are discussed. These results provide information regarding water quality changes with time during critical base flow conditions and expand the limited data base provided by the one-time grab sample.

One-Time Grab Samples

The first set of grab samples was collected the week of March 20, 1978 during moderate flow conditions. Rain on March 21, 1978 provided a substantial volume of runoff. Base flow samples were collected during the week of October 2, 1978. Local sources indicate that base flows in 1978 were the lowest in approximately 30 years. The prevailing weather and flow conditions during both sampling events appeared to be representative of moderate and extreme base flow conditions respectively.

Findings of the one-time grab samples program (moderate and base flow conditions) based on field observations and water quality analyses are summarized for each sampling station in Table I-13. Data from analyses for all water quality parameters sampled during this program are presented in tabular form for review in Appendix I. However, because analyses were performed for such a large number of different parameters, only the results of analyses for those independent parameters considered critical in assessing water quality or of special concern in the study area are presented in this section. These include the following:

- Dissolved Oxygen (D.O.)
- Ammonia Nitrogen (NH_3-N)
- Nitrate Nitrogen (NO_3^--N)
- Total Dissolved Solids (TDS)
- Chloride
- Sulfate
- Total Chromium
- Nickel
- Copper
- Iron
- Zinc
- pH
- Fecal Coliform
- Pesticides

Not all of these parameters are significant for each of the groundwater basins sampled, Turnhole Spring, Echo-Styx and Hidden River Basins. For example, since there are no known sources of chromium, nickel or copper in the Echo-Styx or Turnhole Spring Basins and since moderate flow samples indicate very low concentrations of the metals naturally occurring, they are not considered further in assessing water quality of those basins. Water quality analyses, results and evaluations for each basin are presented below. Because the "aquatic life" classification is presently applied to the subsurface waters in the area, the concentrations of water quality parameters, as determined by analyses, are compared to aquatic life water quality criteria for those parameters (where applicable) in assessing water quality. However, for many toxic materials, aquatic life standards are given in terms of a fraction of the 96-hr LC_{50} of a local sensitive species. (The LC_{50} is the concentration of the particular material lethal to 50% of the species within a 96-hr. period.) Since there is no information on LC_{50}'s for any of the cave species, LC_{50}'s for other sensitive fresh water fish are used to calculate an estimated safe limit. It has been suggested by Dr. Barr of the University of Kentucky, that the blind fish may be able to tolerate temporarily higher levels of toxic materials because of its slower metabolism. (This is discussed more fully in the results of the biological sampling program.)

Turnhole Spring Basin

Significant water quality data for the Turnhole Spring Basin from moderate and base flow grab samples are presented in Figures I-14 to I-22. Based on these data for critical water quality parameters, there appear to be no major pollution problems in the Turnhole Spring Basin.

Dissolved Oxygen (Figure I-14). In both moderate and base flow conditions D.O. concentration at all sampling stations exceeded the minimum requirement for maintaining aquatic life (5 mg/l). In fact, all readings indicated greater than 75% saturation. Although D.O. measurements were not taken in Parker Cave, aquatic life is abundant, indicating satisfactory D.O. concentrations. One sample of Brown River was taken from the cave during low flow for D.O. determination. D.O. in the sample was 8.4 mg/l indicating that the sample in the stream is at least 8.4 mg/l. In addition, D.O. at Mill Hole, the first point of access to the subsurface streams of the Turnhole Spring Basin after Parker Cave, was

TABLE I-13. SUMMARY NOTES* ON RESULTS OF GRAB SAMPLES AT EACH SAMPLING SITE DURING MODERATE AND LOW FLOW SAMPLING CONDITIONS

SAMPLE STATION	DESCRIPTION	MODERATE FLOW COMMENT	BASE FLOW COMMENT
1	Glasgow Uplands (Apple Grove Headwaters)	Total Kjeldahl Nitrogen of 1.1 mg/l is highest of non-polluted waters. May be due to organic decay in the bog area. Meets drinking water and aquatic life water quality criteria.	There was no water at the original sampling site under base flow conditions. The site was moved to a point several yards upstream from site #2. At this station flow was nearly zero. Fecal coliform MPN about 1000/100 ml. Conductivity 65 µmhos. Fecal coliform most likely due to animal wastes since sample was taken in pastureland run-off. Meets drinking water and aquatic life water quality criteria.
2	Guilfoil Spring (Downstream from water supply spring confluence with Apple Grove Stream)	No unusual characteristics water quality good to excellent. Meets drinking water and aquatic life water quality criteria.	Base flow approximately .04 cfs. Fecal coliform MPN diluted to approximately 200/100 ml. Highest MBAS level (.076 mg/l) of all the stream samples. Conductivity up to 256 µmhos, probably a result of the contribution of flow from the spring. Meets water quality criteria for drinking water, aquatic life and bathing.
3	Hog lot Runoff	Fecal coliform MPN high at 2730/100 ml, exceeding drinking water standard. Nitrate nitrogen concentration (2.14 mg/l) was higher than at stations 1 and 2 (.56 and .75 mg/l). Nitrate levels similar to other surface streams in the area. Fecal coliform densities and nitrates due to hog lot runoff. Nitrates indicate stabilized wastes. Meets water quality criteria for aquatic life.	Zero flow.
4	Apple Grove Drainage before Parker Cave	Fecal coliform MPN of 1420/100 ml is less than station 3, but still was high, exceeding standards for secondary contact recreation. Meets water quality criteria for drinking water and aquatic life.	Fecal coliform MPN up, 1500/ml. Nitrate nitrogen concentration (2.94 mg/l) several times larger than upstream samples. Nitrates may be from stabilized animal wastes or fertilizers. Meets water quality criteria for drinking water and aquatic life.

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* Includes-statement regarding water quality criteria. These conclusions are based only upon the grab samples and do not necessarily reflect water quality at all times.

TABLE I-13. SUMMARY NOTES ON RESULTS OF GRAB SAMPLES AT EACH SAMPLING SITE DURING MODERATE AND LOW FLOW SAMPLING CONDITIONS (Cont'd.)

SAMPLE STATION	DESCRIPTION	MODERATE FLOW COMMENT	BASE FLOW COMMENT
5	Parker River (near cave entrance)	Nitrate nitrogen higher than any other stream sample (5.8 mg/l), typical of runoff in agricultural areas. Meets water quality criteria for drinking, aquatic life, and bathing.	Nitrate nitrogen down from moderate flow sampling (1.81 mg/l) since runoff source is not present. Meets water quality criteria for drinking, aquatic life and bathing.
6	Parker River (downstream from Apple Grove tributary)	Total dissolved solids (TDS) (608 mg/l) sulfate (136 mg/l) and chloride (200 mg/l) levels are higher than all other stream samples. Indication of oil brine pollution, but still meets drinking water standards. The point of chloride pollution is not known. It is likely that the Apple Grove drainage stream is contaminated between its sinking point and its confluence with Parker River. Meets water quality criteria for drinking water, aquatic life, and bathing.	Nitrate nitrogen higher than station 4 (5.36 mg/l). Conductivity (5,130 µmhos/cm) and TDS (3,400 mg/l) exceed drinking water standards. However, blind fish and blind crayfish are present in stream. Meets water quality criteria for aquatic life.
7	Sulfur Spring tributary to Parker River	Known source of chloride and sulfate contamination. Supported by data; chloride (184 mg/l) and sulfate (26 mg/l). However, this contamination is less than that detected at station 6. Meets water quality criteria for aquatic life.	Chloride and sulfate contamination is again evident. However, chloride level of 1,180 mg/l far exceeds drinking water standard of 250 mg/l. Aquatic life appear to be unaffected. Meets water quality criteria for aquatic life.
8	Brown River	Suspended solids of 29 mg/l indicates runoff. Total phosphorus of .116 mg/l is higher than other streams in the area possibly due to agricultural runoff. Meets water quality criteria for drinking waters and aquatic life.	Water of high quality, BOD_5 approximately 0 and dissolved oxygen $\geq$8.4 mg/l. Nitrate nitrogen is 3.35 mg/l, typical of area waters. Meets water quality criteria for drinking waters, aquatic life, and bathing.
9	Parker River (final sample in Parker Cave)	TDS (560 mg/l), conductivity (600 µmhos/cm), sulfate (128 mg/l) and chloride (180 mg/l) levels remain high due to upstream sources (stations 6 and 7). Zinc concentration of 0.108 mg/l is higher than other streams. Zinc concentrations appear to be from runoff. Although this concentration would be toxic to some fish, blindfish appear to be unaffected as many were seen during sampling. Meets water quality criteria for drinking water, aquatic life and bathing.	TDS (2520 mg/l), conductivity (3,740 mg/l), again are high. Nitrate nitrogen at 6.5 mg/l is higher than stations 6 and 7. Nitrate possibly indicates stabilized pollutants. Meets water quality criteria for aquatic life and bathing.

TABLE I-13. SUMMARY NOTES ON RESULTS OF GRAB SAMPLES AT EACH SAMPLING SITE DURING MODERATE AND LOW FLOW SAMPLING CONDITIONS (Cont'd.)

SAMPLE STATION	DESCRIPTION	MODERATE FLOW COMMENT	BASE FLOW COMMENT
10	North Creek headwaters (small subsurface drainage area)	Water quality excellent. Good indicator of ambient water quality. Nitrate nitrogen concentration 3.98 mg/l. Meets water quality criteria for drinking water, aquatic life, and bathing.	Nitrate nitrogen 4.00 mg/l best example of typical "unpolluted" groundwater. Meets water quality criteria for drinking water, aquatic life, and bathing.
11&12	Phantom Sulfur Spring Area	No samples collected	Represents extreme chloride and sulfate pollution. Significant quantities of H_2S also present indicating reducing conditions (low oxygen levels). Chloride concentration at the spring 8,920 mg/l and sulfate 247 mg/l. Sulfide (as S) present (9.3 mg/l). No fish life in the waters.
14	Mill Hole	Water quality excellent. Fecal coliform MPN level of 320/100 ml less than 2000/100 ml criteria for secondary contact recreation. Relatively low fecal coliform for the large amount of runoff flowing to Mill Hole. Meets water quality criteria for drinking water, aquatic life and secondary contact recreation.	Water quality excellent at base flow. Dissolved oxygen about 8.5 mg/l and fecal coliform MPN of 120/100 ml meets water quality criteria for bathing waters. Meets water quality criteria for drinking water, aquatic life, and bathing.
15	Cedar Sink (mod. flow) Owl Cave (base flow)	Water quality excellent. Fecal coliform MPN of 140/100 ml meets bathing water criteria. BOD_5 low - 1.2 mg/l. No evidence of pollution from Park City wastewaters. Meets water quality criteria for drinking water, aquatic life and bathing.	Water quality excellent; $BOD_5 < 1$ mg/l, D.O. about 8.1 mg/l and a fecal coliform MPN of 0/100 ml. No evidence of pollution from Park City wastewaters. Meets water quality criteria for drinking water, aquatic life, and bathing.
16	Echo River	Water quality excellent, no evidence of pollution. Meets water quality criteria for drinking water, aquatic life, and bathing.	Water quality excellent, no evidence of pollution. Meets water quality criteria for drinking water, aquatic life, and bathing.

TABLE I-13. SUMMARY NOTES ON RESULTS OF GRAB SAMPLES AT EACH SAMPLING SITE DURING MODERATE AND LOW FLOW SAMPLING CONDITIONS (Cont'd.)

SAMPLE STATION	DESCRIPTION	MODERATE FLOW COMMENT	BASE FLOW COMMENT
17	South Branch Hidden River Cave	Data indicate severe pollution from Horse Cave STP. Trace metals contamination, high water temperature (13° C) for cave waters, high BOD_5 (133 mg/l) almost as strong as raw sewage (200 mg/l) and dissolved oxygen of 3.9 mg/l. Not suitable for aquatic life. Other pollutants evident in high concentration TDS, TSS, MBAS, ammonia nitrogen and sulfate.	Data indicate cave is still severely polluted by the Horse Cave STP. Trace metals concentrations down from moderate flow conditions due to Ken Dec, Inc. pre-treatment facilities. Some metals concentrations still toxic to some aquatic life (e.g. Copper, Zinc, Chromium). Water temperature of 19° C and D.O. level 2.7 mg/l. Little oxygen in air or water. Severe stench coming from entrance to cave. Will not support aquatic life.
18	East Branch Hidden River	Water quality excellent. No significant evidence of pollution - Nitrate nitrogen - 3.79 mg/l. Meets water quality criteria for drinking water, aquatic life and bathing.	BOD_5 high for natural waters (8.9 mg/l) indicating organic pollution, fecal coliform MPN of 17,500/100 ml is very high. High conductivity and TDS. D.O. level, however, was 7.9 mg/l. Data seems to support Quinlan's report that during low flow the East Branch is contaminated by the South Branch by seepage under the rocks immediately upstream from their confluence. Cave City could contribute some pollution, however, it is not considered likely that D.O. levels could be as high as 7.9 mg/l for long at BOD_5 concentrations of 8.9 mg/l. This indicates recent contamination. Meets water quality criteria for aquatic life.
19	Blue Spring Branch	Water quality excellent. No evidence of pollution. Fecal coliform MPN 0/100 ml. Meets water quality criteria for drinking water, aquatic life, and bathing.	Water quality generally good to excellent. Meets water quality criteria for drinking water, aquatic life and bathing.
20	L & N Cave	Water quality excellent. Meets water quality criteria for drinking water, aquatic life and bathing.	Water quality generally good. However, nitrate level is very high compared with all other sampling locations. Nitrate concentration of 10 mg/l is equal to maximum allowed for drinking water. Source may be stabilized wastes or fertilizer. Meets water quality criteria for drinking water, aquatic life and bathing.

TABLE I-13. SUMMARY NOTES ON RESULTS OF GRAB SAMPLES AT EACH SAMPLING SITE DURING MODERATE AND LOW FLOW SAMPLING CONDITIONS (Cont'd.)

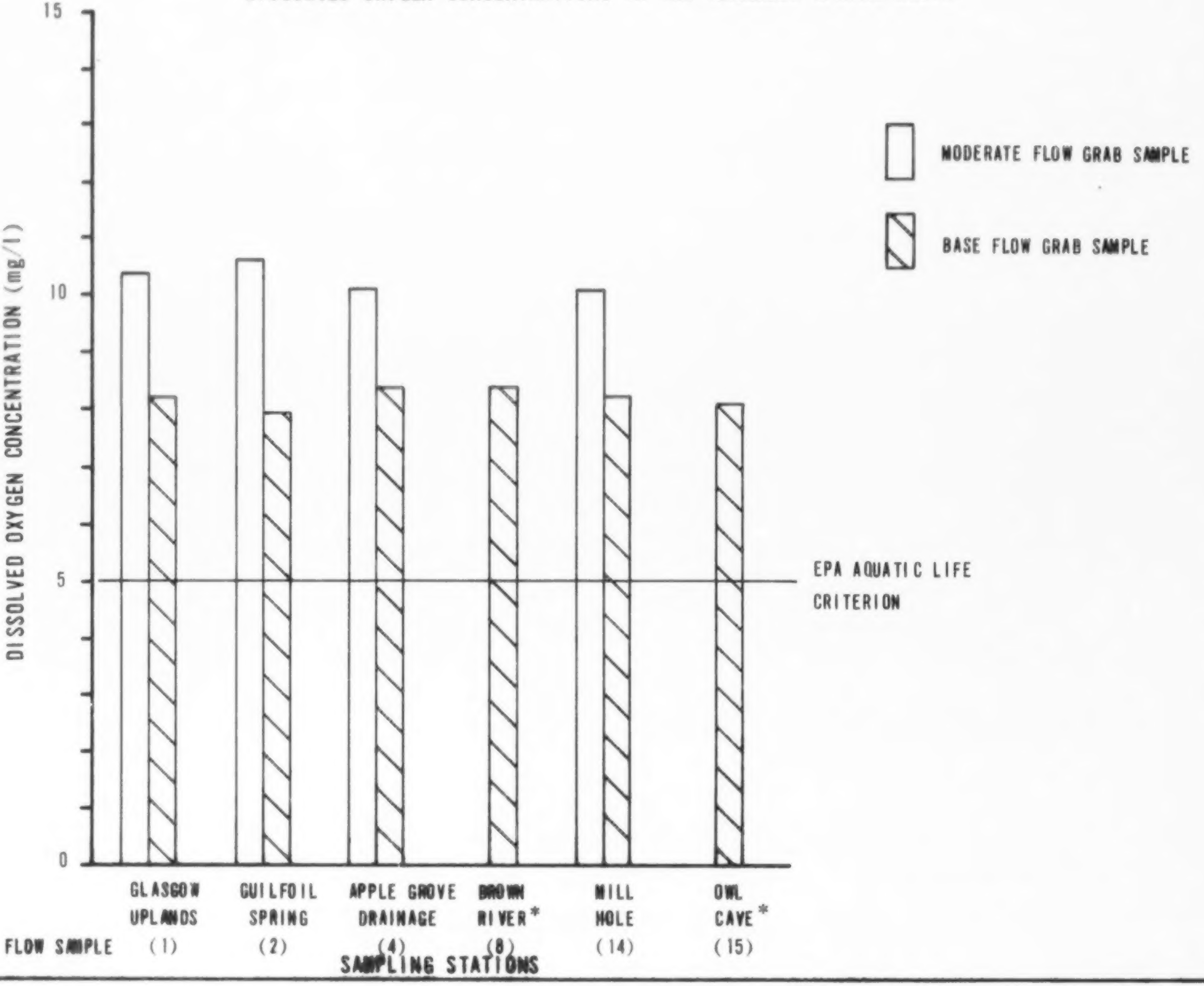
SAMPLE STATION	DESCRIPTION	MODERATE FLOW COMMENT	BASE FLOW COMMENT
21	Hick Spring (mod. flow) Gorin Mill Spring (base flow)	Water quality excellent. Heavy metals from Horse Cave STP not detected. D.O. near saturation, 10.6 mg/l. Meets water quality criteria for drinking water, aquatic life and bathing.	Water quality poor. With respect to D.O. level of 2.7 mg/l this is too low to support aquatic life. Slight odor detected. However, fecal coliform MPN of 0/100 ml and BOD_5 of 1.2 mg/l are indicative of high quality waters. Low levels of all pollutants appear to indicate that low D.O. is caused by lack of reaeration in the cave. Meets water quality criteria for drinking water and bathing.
26	Ken-Dec, Inc. effluent	Heavy metals far exceed pre-treatment standards Ken-Dec mg/l — Pre-Treatment Standard mg/l (max. for any day) Cr^{+6} 30.0 — .25 Cr(total) 34.7 — 4.2 Ni 29.4 — 3.6 Cu 9.1 — 4.6 Substantial quantities of grease and oil (63 mg/l)	Pre-treatment standard maintained for all heavy metals except hexavalent chromium (Cr^{+6}). Sample indicates 0.44 mg/l. Grease and oil less than 3 mg/l.
27 & 28	Cave City Wastewater Treatment Plant (influent and effluent)	Effluent BOD_5 and total suspended solids (TSS) very high, 148 mg/l and 108 mg/l respectively. Treatment plant functioning far below design efficiency. Grease and oil concentration (103 mg/l) is high. Ammonia nitrogen high - 24.4 mg/l.	BOD_5 and TSS near secondary treatment levels, 47 mg/l BOD_5 and 30 mg/l TSS. Efficiency much improved from moderate flow sampling conditions. Grease and oil about 11 mg/l and ammonia nitrogen about 28 mg/l.

TABLE I-13. SUMMARY NOTES ON RESULTS OF GRAB SAMPLES AT EACH SAMPLING SITE DURING MODERATE AND LOW FLOW SAMPLING CONDITIONS (Cont'd.)

SAMPLE STATION	DESCRIPTION	MODERATE FLOW COMMENT	BASE FLOW COMMENT
29 & 30	Horse Cave Wastewater Treatment Plant (influent and effluent)	Influent heavy metals concentrations are toxic to treatment plant microorganisms, exceeding even the pretreatment standards for metal plating facilities.	No influent comment
		Effluent BOD_5 of 96 mg/l and TSS of 41 mg/l do not meet secondary treatment standards. However, some removal is experienced in spite of the adverse conditions.	Effluent BOD_5 of 361 mg/l and TSS of 151 mg/l are extremely high due to dumping of digestor supernatant on day of sampling.
		Effluent concentrations of heavy metals are extremely high. Cr^{+6} 7.9 mg/l Cr(total) 16.7 mg/l Ni 12.3 mg/l Cu 6.6 mg/l Zn 0.584 mg/l	Effluent metals remain higher than normal wastewater treatment plants, but much reduced from moderate flow. Cr^{+6} 0.06 mg/l Cr(total) 2.42 mg/l Ni 3.57 mg/l Cu 0.59 mg/l

FIGURE I-14

DISSOLVED OXYGEN CONCENTRATIONS IN THE TURNHOLE SPRING BASIN



* NO MODERATE FLOW SAMPLE

8.5 mg/l during base flow. As expected, base flow D. O. at all locations was less than moderate flow D. O. concentrations. Because BOD_5 values in the stream are similar for both flow conditions, these differences are probably due to higher water temperatures and/or less reaeration during base flow.

Ammonia Nitrogen (Figure I-15) - Both moderate and base flow samplings indicate ammonia levels to be acceptable for meeting the EPA aquatic life criteria. Ammonia nitrogen occurs in two forms, the ammonium ion (NH_4+) and un-ionized ammonia (NH_3). The relative concentration of each depends on temperature and pH, with NH_3 becoming the dominant form at higher temperatures and/or pH levels. This is also the toxic form, subject to a limit of 0.02 mg/l in the EPA aquatic life criteria. However, since our analyses were for total ammonia, this limit is indicated in Figure I-15 in terms of total ammonia for pH 8 and 8.5 and at 20°C and 15°C. Since pH levels at all the Turnhole Spring sampling stations were less than 8, the ammonia nitrogen levels are satisfactory for maintaining aquatic life.

The low levels of ammonia in the streams indicate a lack of fresh sources of organic pollution. Also the higher ammonia concentrations during moderate flow indicate the effects of runoff from vegetated or agricultural area.

Nitrate Nitrogen (Figure I-16) - Nitrate nitrogen concentrations are not known to have a significant impact on aquatic life at levels found in even heavily polluted waters. However, a limit of 10 mg/l is required for public drinking water supplies because of adverse health effects on infants. All moderate and base flow grab samples indicate that nitrates are well within this range in the Turnhole Spring Basin. The major sources of nitrates in the Turnhole system are fertilizers and stabilized animal waste. However, the relatively high concentration of nitrates in Owl Cave recorded during base flow (6.87 mg/l) may indicate stabilized human wastes from Park City via the Patoka Trunk Stream.

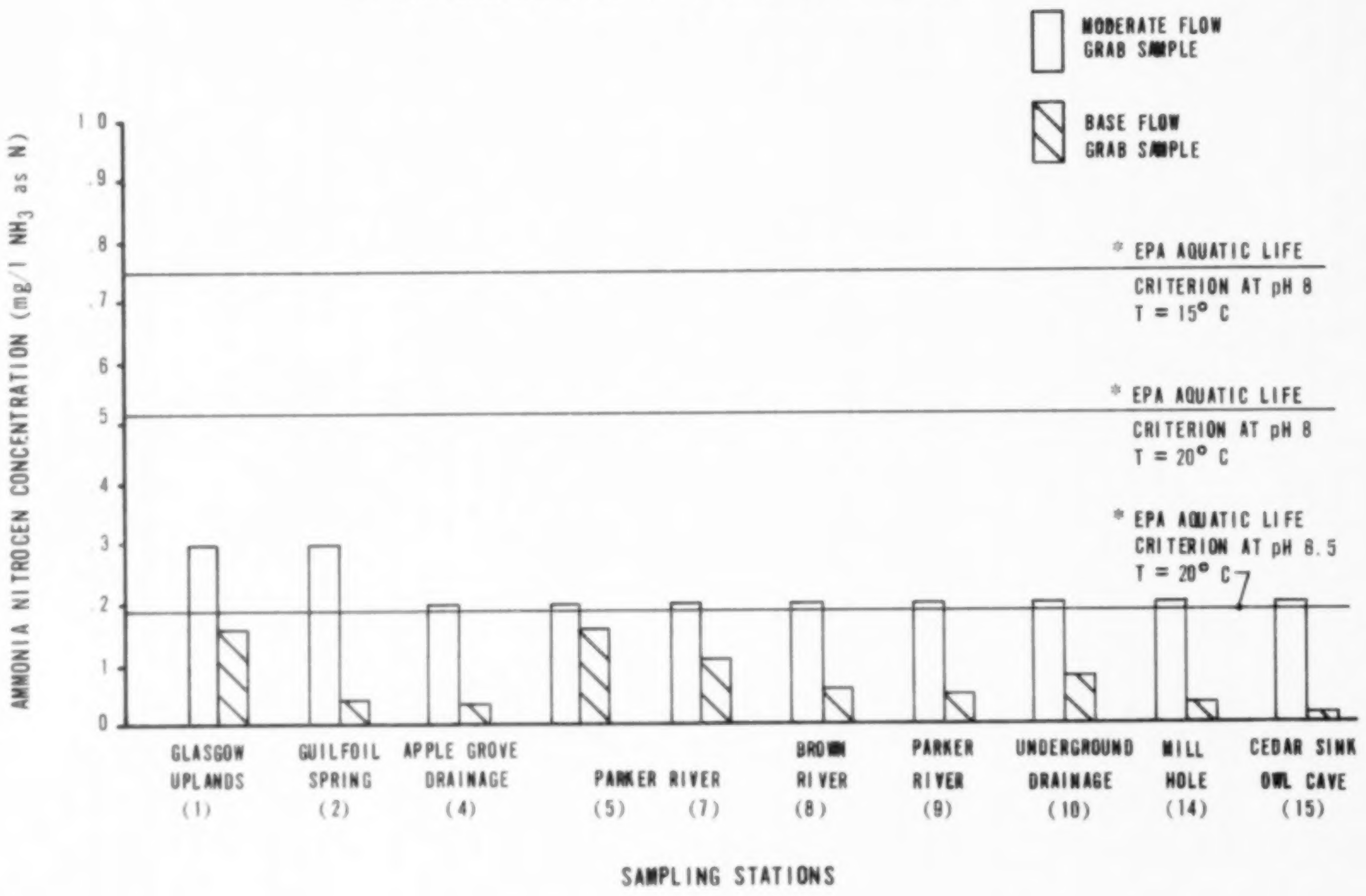
Total Dissolved Solids (TDS) (Figure I-17) - Total dissolved solids concentrations were found to exceed the proposed Kentucky drinking water standards at five sampling locations in the Turnhole Spring Basin during base flow conditions, three sites in Parker River and at the two sampling stations at the Phantom Sulfur Spring. These dissolved solids levels appear to be due to chloride and sulfate pollution from brines leaking from abandoned oil wells. The TDS levels in Parker River do not appear to affect aquatic life since several blind fish and blind crayfish were observed during sampling. No aquatic life was observed in the vicinity of the Phantom Sulfur Spring.

The pollution resulting from oil brines appears to be a local problem since samples collected at Mill Hole and Cedar Sink, which represent composites of the entire drainage area, contained much lower concentrations of TDS, meeting drinking water standards.

The Parker River TDS pollution is first evident immediately downstream from the confluence of Parker River and the Apple Grove Drainage. It appears that at some point between where the Apple Grove stream sinks and where it joins Parker River, it is contaminated (The Parker river upstream of the confluence (station 6) has a TDS concentration significantly less than downstream). The Phantom Spring itself appears to be a primary source of contamination since TDS levels (chloride and sulfate) are so high.

FIGURE I-15

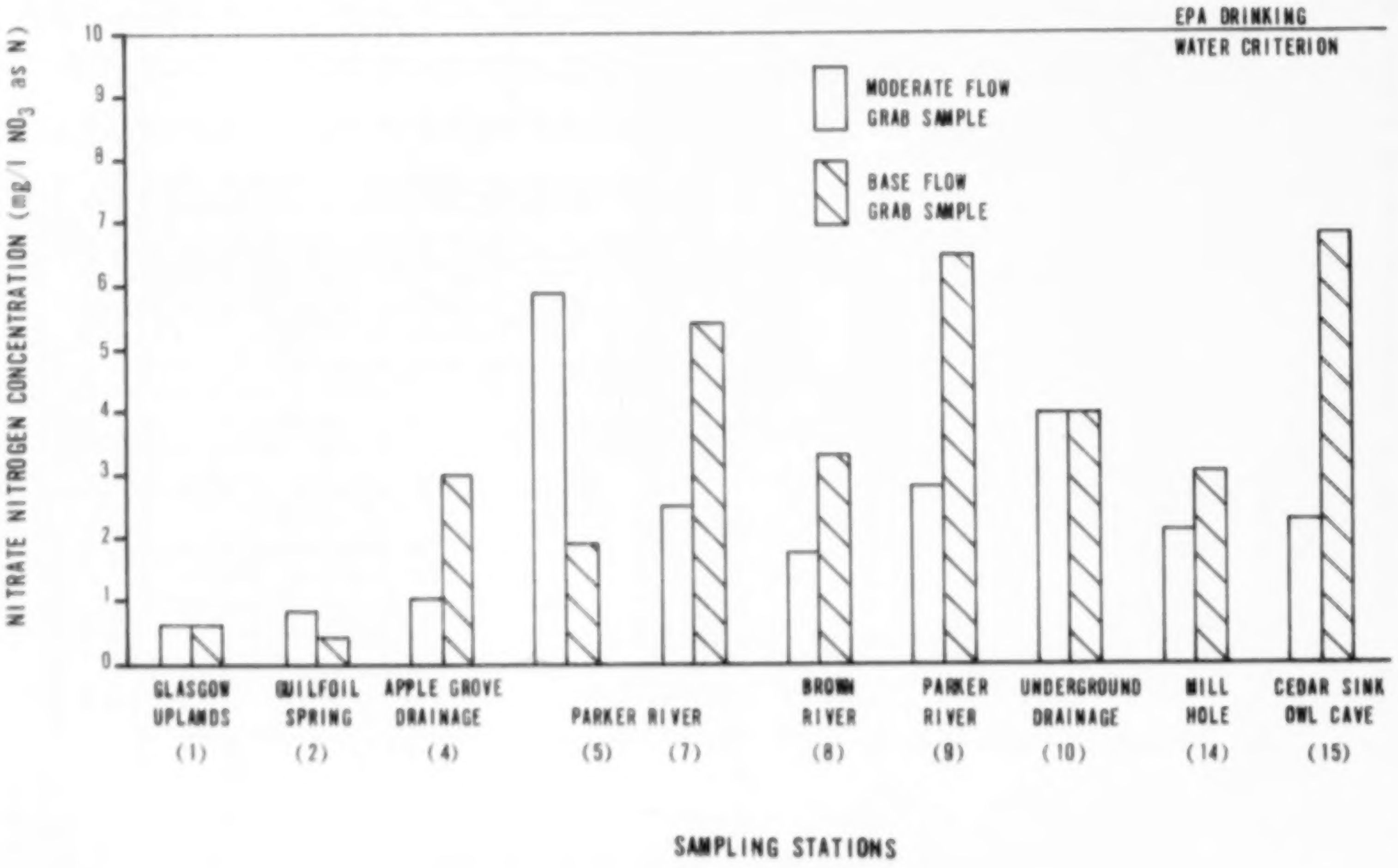
AMMONIA CONCENTRATIONS IN THE TURNHOLE SPRING BASIN



* BASED ON .02 mg/l UN-IONIZED AMMONIA

FIGURE I-16

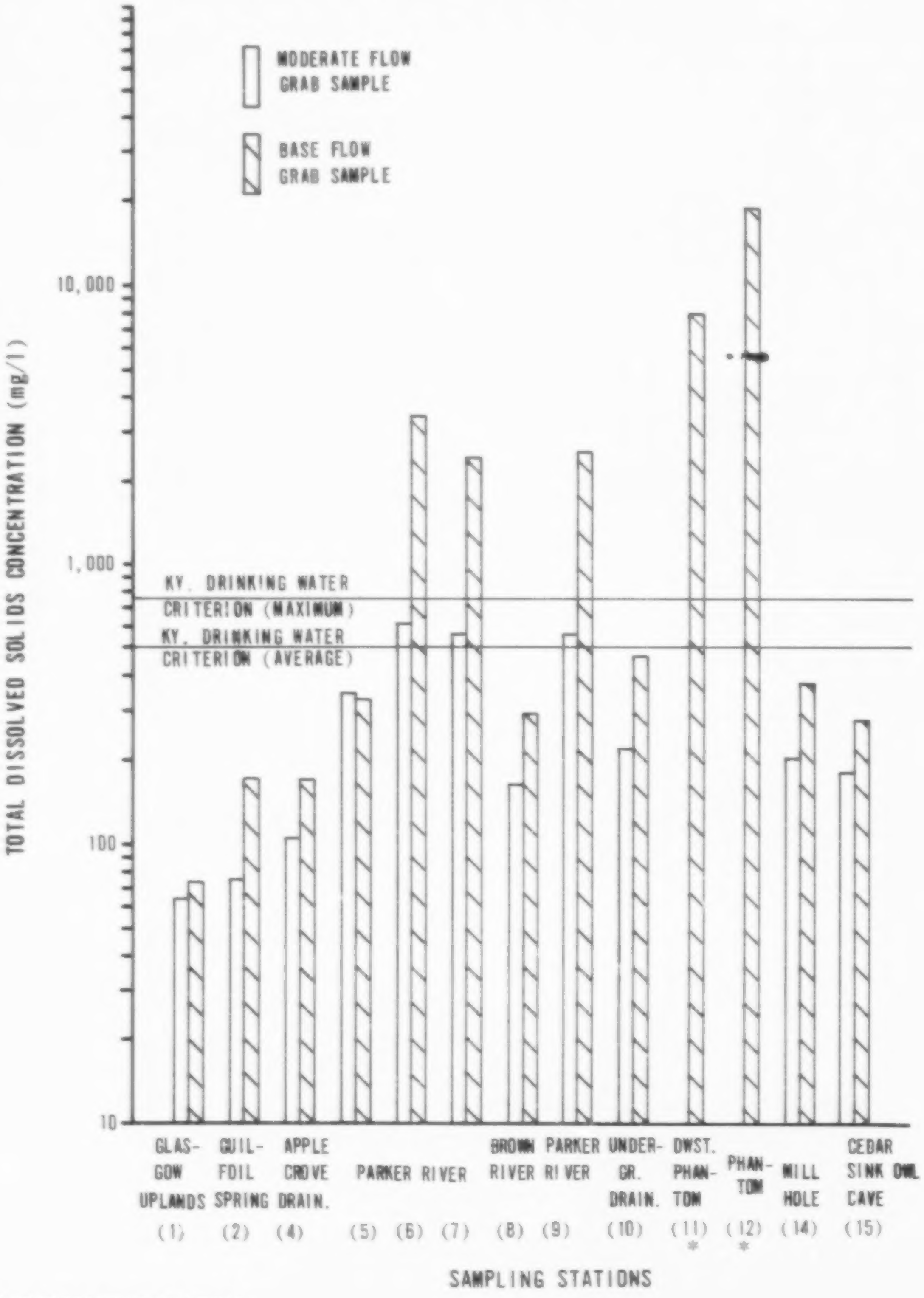
NO_3-N CONCENTRATIONS IN THE TURNHOLE SPRING BASIN



I-61-b

FIGURE I-17

TOTAL DISSOLVED SOLIDS CONCENTRATIONS IN THE TURNHOLE BASIN



* NO MODERATE FLOW SAMPLE

Chloride (Figure I-18) - Chloride concentrations were found to exceed drinking water quality standards at three sampling locations in the Turnhole Spring Basin during base flow conditions. TDS levels at these sites were also excessive. Chloride analyses were not performed on samples from the other two sites with excessive TDS levels (see TDS summary).

Sulfate (Figure I-19) - (See TDS Summary) Sulfate levels in the Turnhole Spring Basin were not found to exceed Kentucky drinking water standards. However, concentrations significantly higher-than-background were noted in Parker River and in the Phantom Sulfur Spring.

Although sulfate concentrations do not appear to be critically high even at the Phantom Spring, reducing conditions at the Phantom cause the formation of hydrogen sulfide in concentrations lethal to some aquatic life.

Chromium, Copper and Nickel - Data from analyses for these metals in the Turnhole Spring Basin are not included in this section since there are no known significant sources in the drainage area. Base flow sampling at Owl Cave, which receives drainage from the Park City area, indicates the following concentrations: (1) Chromium-0.01 mg/l; (2) Nickel-<0.01 mg/l; and (3) Copper-0.01 mg/l. These background levels are within the limits necessary to support even sensitive aquatic life.

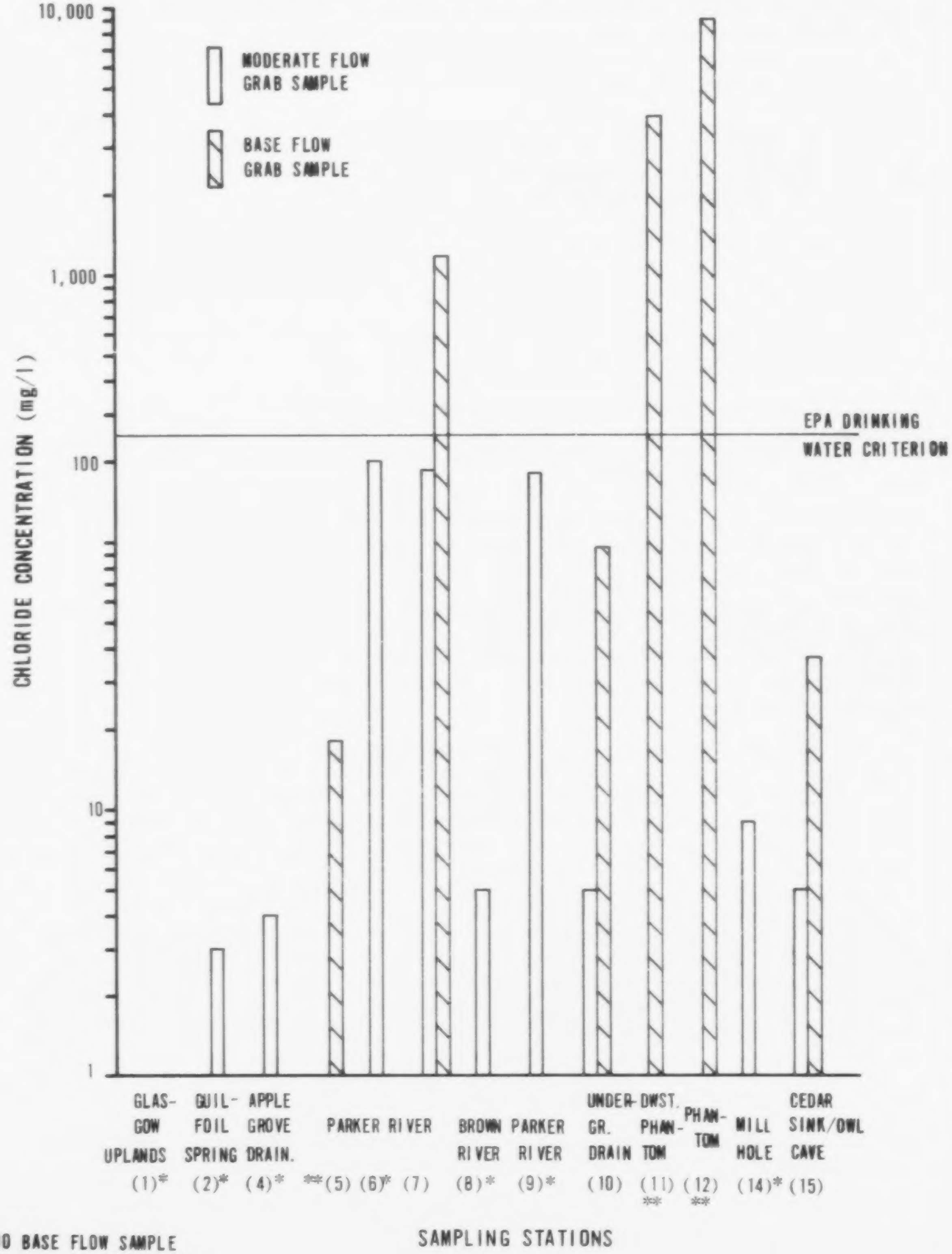
Iron (Figure I-20) - Although iron is not considered to be a significant cause of pollution problems in the area, the relatively high concentrations detected during the moderate flow sample warrant some consideration. At every sampling station in the Turnhole Spring Basin, iron concentrations exceeded the EPA drinking water criteria during the moderate flow sampling; four exceeded the EPA aquatic life criteria. However, sampling during base flow conditions at the Apple Grove drainage stream (#4), site of the highest iron concentration during moderate flow (3 mg/l), indicated iron concentrations well within drinking water limits and the aquatic life criterion.

The moderate flow iron samples were reanalyzed, yielding similar results. Other than the possibility of contamination of all the moderate flow samples, there appears to be a possible explanation. Under aerobic conditions, the ferric (Fe^{+++}) form of iron is most prevalent and, for practical purposes, insoluble. However, under anaerobic conditions, the ferric iron is reduced to ferrous (Fe^{++}) which is soluble. During long periods of saturation, soils with significant amounts of organic material may become anaerobic due to oxygen consumption by micro-organisms responsible for bio-degradation of the organic material. (The Glasgow Uplands soil in swamp areas contains much organic material as do the pasture lands near Apple Grove). Insoluble ferric iron, naturally occurring in the soils, could have been reduced to soluble ferrous iron, under anaerobic conditions. Since moderate flow samples were collected immediately following a rainfall, this ferrous iron may have been leached out of the soils.

Another possibility is that naturally occurring organometallic iron compounds may be carried into the streams with the rainfall. These forms of iron are not considered to have any significant affect on aquatic life since they are relatively chemically and physiologically inactive.

FIGURE I-18

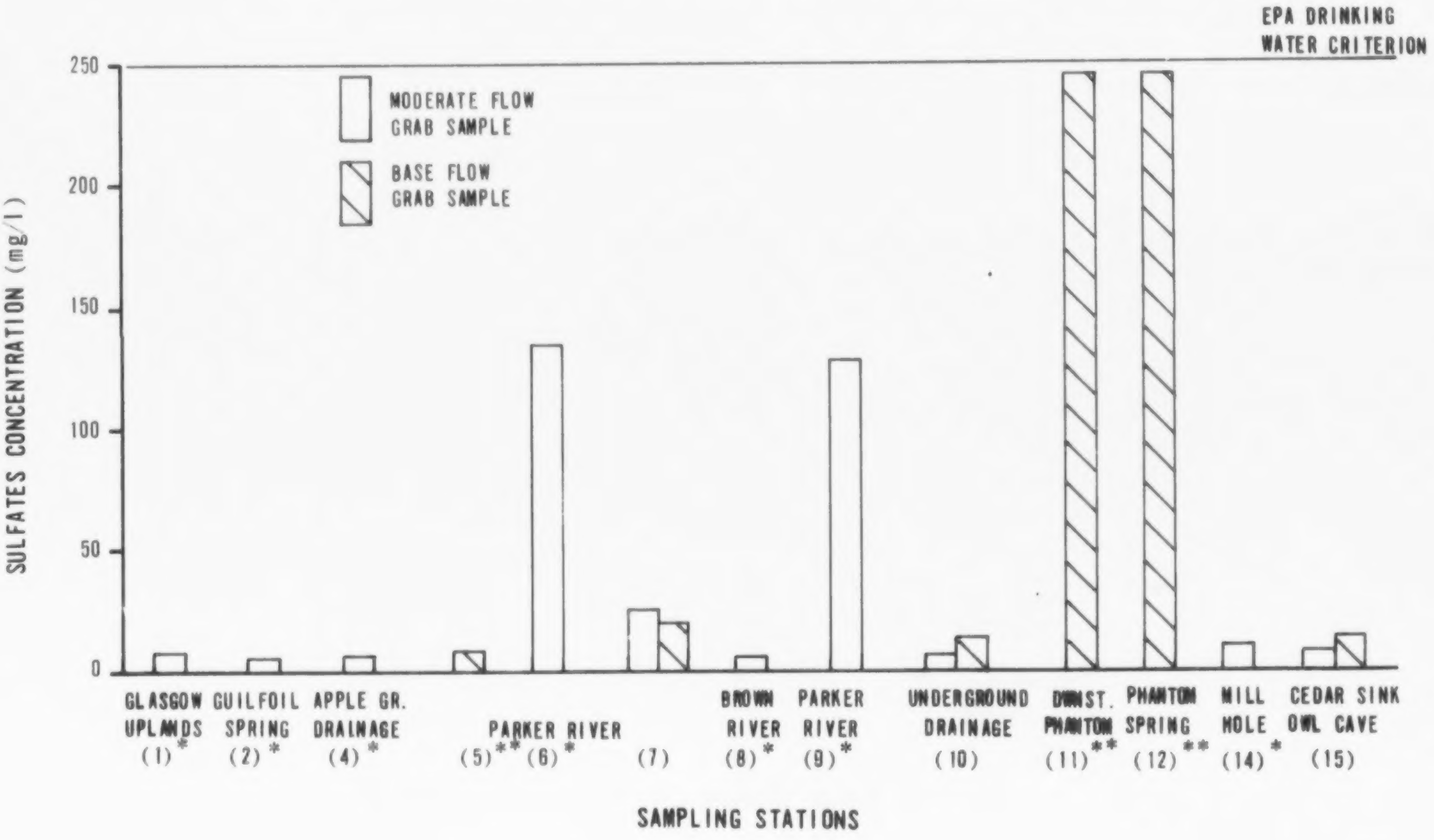
CHLORIDE CONCENTRATIONS IN THE TURNHOLE SPRING BASIN



* NO BASE FLOW SAMPLE
** NO MODERATE FLOW SAMPLE

FIGURE I-19

SULFATE CONCENTRATIONS IN THE TURNHOLE SPRING BASIN

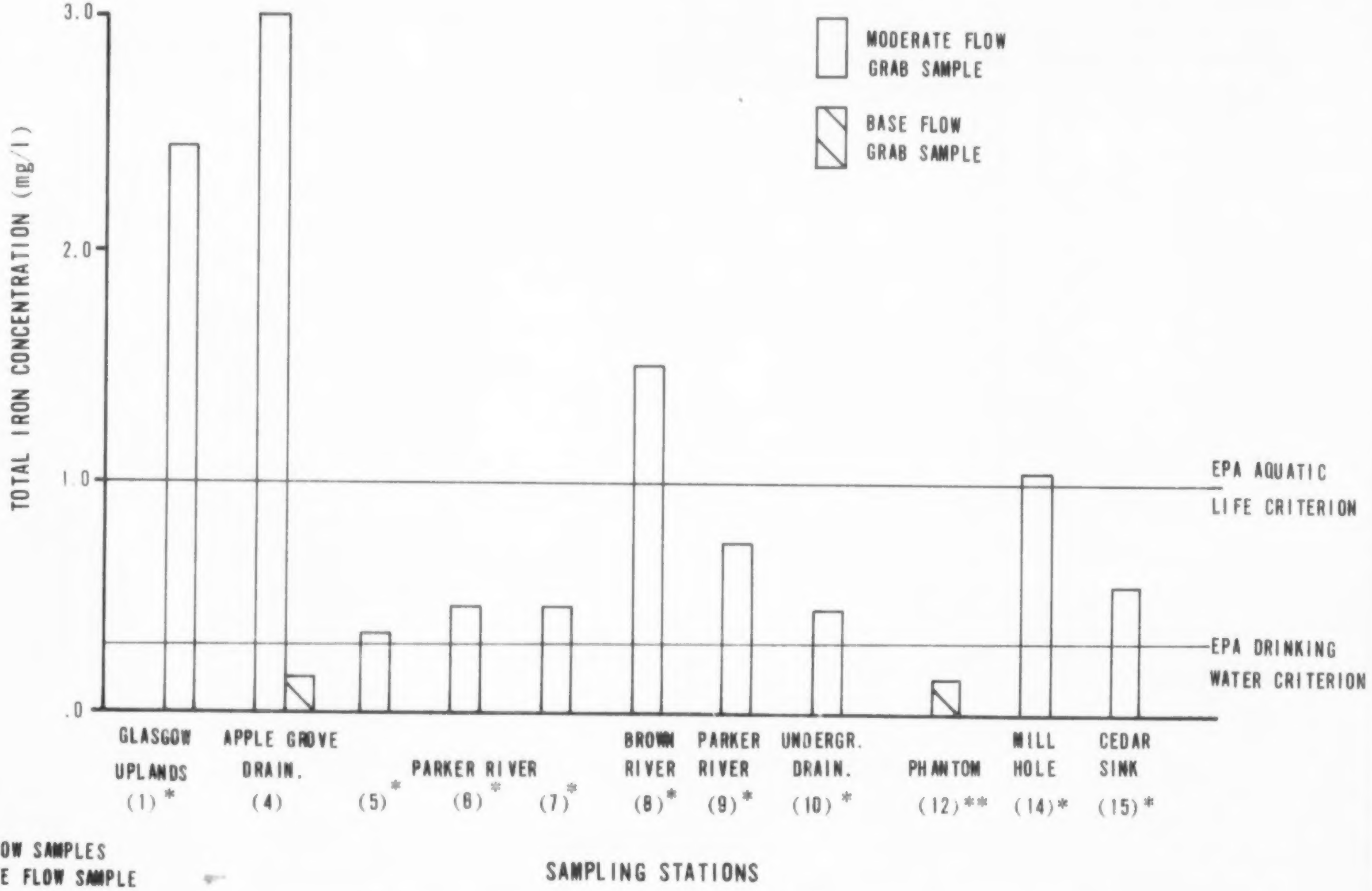


* NO BASE FLOW SAMPLE

** NO MODERATE FLOW SAMPLE

FIGURE I-20

IRON CONCENTRATIONS IN THE TURNHOLE SPRING BASIN



* NO BASE FLOW SAMPLES
** NO MODERATE FLOW SAMPLE

Based on the large differences between base flow and moderate flow iron concentratives, it appears that high iron concentrations are temporary phenomena associated with runoff. It does not appear that this condition poses a threat to water quality.

Zinc (Figure I-21) - Based on moderate flow sampling, it appears that zinc occurs naturally in Turnhole Spring Basin waters. For example, in the Glasgow Uplands Headwaters area zinc concentration during moderate flow conditions was 0.06 mg/l. This is higher than the estimated safe limit for trout; however, it is still much less than that for minnows (See Figure I-22). Base flow grab samples at Brown River and Owl Cave indicate that the higher zinc concentrations may be associated with runoff, similar to iron, the Brown River base flow zinc concentration is only approximately 60% of the moderate flow and the Owl Cave zinc concentration is only about 35% of the moderate flow.

Since zinc levels appear to be a result of natural events and since aquatic life continues to exist even at the highest observed zinc concentration (Parker River), zinc does not appear to present water quality problems in the Turnhole Spring Basin.

pH - All pH levels observed in the Turnhole Spring Basin under moderate and base flow conditions are within the acceptable range for aquatic life.

Fecal Coliform (Figure I-22) - With respect to fecal coliform densities, water quality in the Turnhole Spring Basin is good to excellent. According to both samplings, fecal coliform densities in some waters (eg. Owl Cave and Cedar Sink) appear to meet the bathing water criterion. This is especially significant since Park City wastewaters are tributary to Owl Cave/Cedar Sink. Waters at all sampling stations appear to meet the secondary contact recreation criterion which is required for subsurface waters of Kentucky (40 CFR 120.21). The highest fecal coliform densities were found in the Apple Grove drainage stream which flows through a cow pasture. No samples revealed any indication of significant human pollution.

Pesticides - Samples were collected for pesticide analyses from the Apple Grove drainage stream (#4) during moderate and base flow conditions and from Mill Hole (#14) during base flow conditions. Results of pesticide scans for Lindane, Endrin, Methoxychlor and Toxaphene indicate concentrations of these materials were less than the limits of detection in all samples:

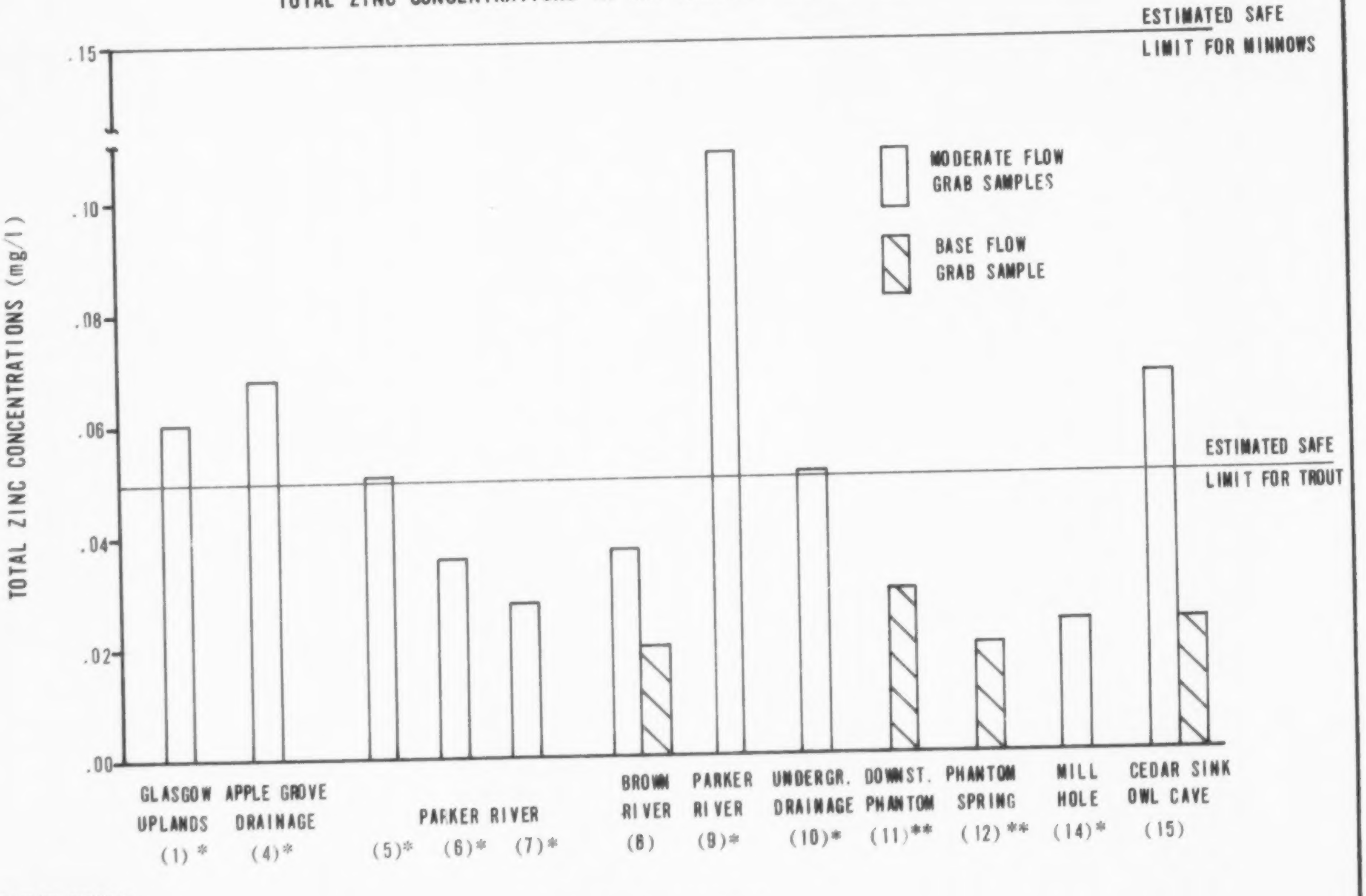
Lindane - <.0001 mg/l
Endrin - <.00002 mg/l
Methoxychlor - <.0001 mg/l
Toxaphene - <.0001 mg/l

Hidden River Basin

The major known pollution problems in the study are in the Hidden River Basin, primarily the result of the discharge of the Horse Cave wastewater treatment plant effluent to the South Branch of Hidden River Cave. Heavy organic loadings and high concentrations of trace metals have destroyed all aquatic life in the South Branch of Hidden River Cave and for some unknown distances downstream of the confluence with the East Branch. In addition, offensive odors resulting from organic decay emanate from the mouth of the cave and create a nuisance in the City of Horse Cave. These problems are well documented by Quinlan and Rowe* and in Section 3 of this report. Although the concentration of toxic metals entering the treatment plant have been substantially reduced by

FIGURE I-21

TOTAL ZINC CONCENTRATIONS IN THE TURNHOLE SPRING BASIN

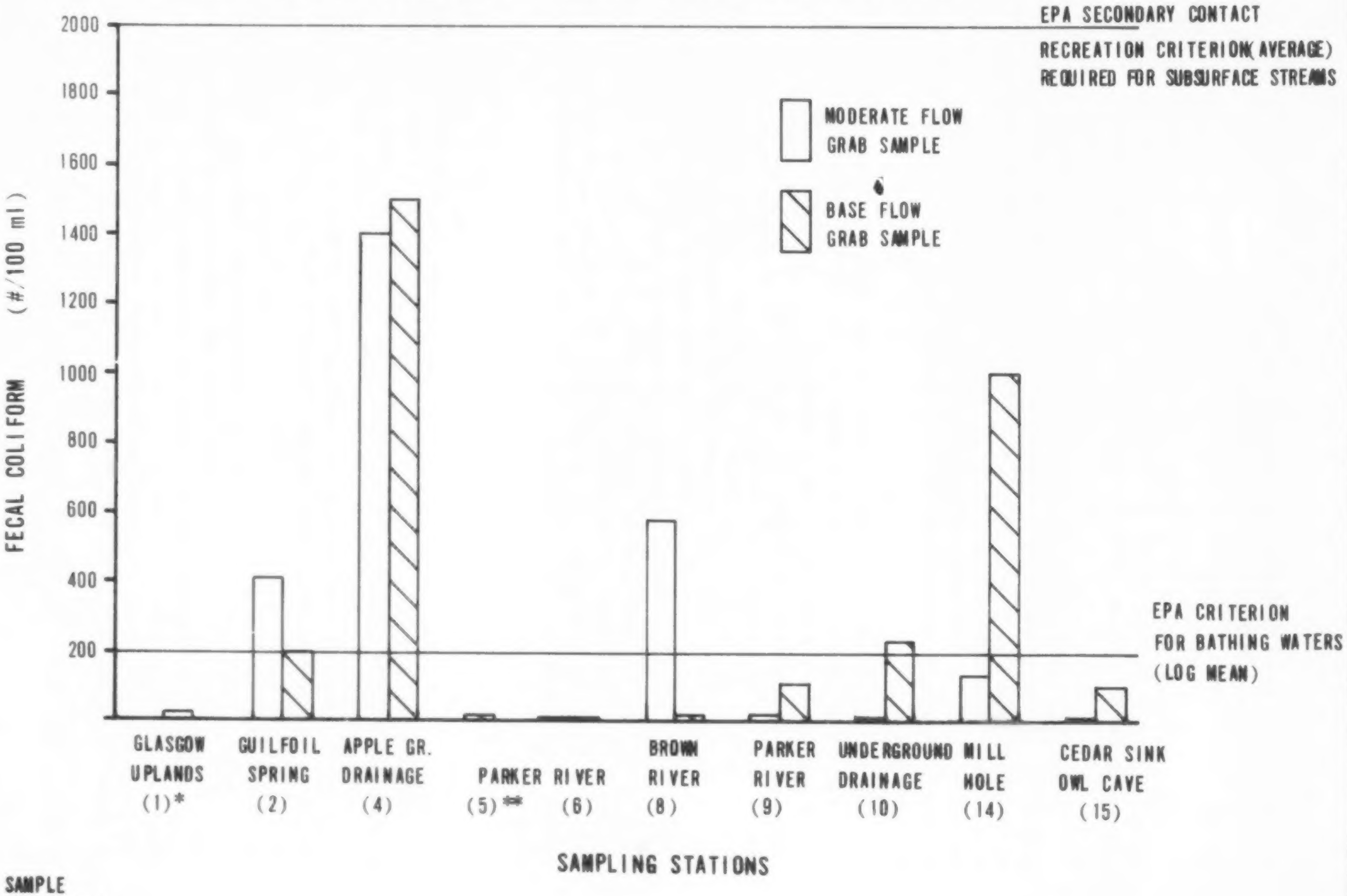


* NO BASE FLOW SAMPLE

** NO MODERATE FLOW SAMPLE

FIGURE I-22

FECAL COLIFORM DENSITIES AT TURNHOLE SPRING BASIN SAMPLING SITES



* NO BASE FLOW SAMPLE

** NO MODERATE FLOW SAMPLE

by industrial pre-treatment at the Ken-Dec electro-plating facility, residuals at the plant continue to limit treatment effectiveness. Therefore, large quantities of untreated organic wastes are entering the cave.

The effects of the discharge on water quality in moderate and base flow conditions are demonstrated by the results of water quality analyses for critical parameters. These results are illustrated in Figures I-23 to I-34.

Dissolved Oxygen (Figure I-23) - Dissolved oxygen levels in South Branch Hidden River Cave during both moderate and base flow conditions are insufficient to maintain aquatic life. This is expected since organic loadings from the Horse Cave treatment plant are large and adequate dilution is not available in the South Branch. The most significant result of this sampling program is the extremely low D.O. concentration (2.5 mg/l) found in the waters of Gorin Mill Spring.

Previous sampling for metals done by Quinlan and Rowe indicate that enough dilution is available from East Branch Hidden River and other waters in the Cave (even during base flow conditions) that metals concentrations are substantially reduced in the series of Hidden River Springs along the Green River. However, low D.O.'s at Gorin Mill Spring during base flow conditions indicate that the stream is not recovered from organic pollution. Since the BOD_5 at Gorin Mill Spring during base flow was determined to be approximately 2 mg/l, it appears that wastes are stabilized upstream but the waters are not re-aerated. This could be due to a lack of oxygen in the cave or lack of an adequate free suface to permit re-aeration of the Gorin Mill flow. Because Gorin Mill Spring is the major discharger from Hidden River Cave and because the base flow D.O. concentration in Gorin Mill is inadequate to support aquatic life, the adverse effects of the Horse Cave discharge may be more far reaching than earlier anticipated.

The dissolved oxygen level in East Branch Hidden River Cave during the base flow conditions is also of interest. Even though the Cave City discharge is tributary to the East Branch, D.O. is relatively unchanged from "upstream" D.O. in Blue Spring Branch. However, the measured BOD_5 concentration (approximately 9 mg/l) indicates organic waste concentrations greater than generally expected for a stream with such a relatively high D.O. level, assuming the wastes have been in the stream long enough to undergo some degradation. If BOD_5 concentrations in the East Branch were higher upstream due to a Cave City tributary, one would expect a depressed D.O. level. It appears likely that the organic wastes in the East Branch may enter the stream almost immediately upstream of the sampling point. One possible source is contamination from the South Branch, though work by Quinlan and Rowe indicates that the magnitude of contamination (0.1%) is not enough to significantly impact waste concentrations measured in the East Branch. Another possible source is the tributary stream containing the Cave City effluent. If this stream joins the main portion of the East Branch immediately upstream from the sampling point, dissolved oxygen concentrations would

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* Hydrologic Water Quality in the Central Kentucky Karst-Phase II, Par. A.

FIGURE I-23

DISSOLVED OXYGEN CONCENTRATIONS IN THE HIDDEN RIVER BASIN

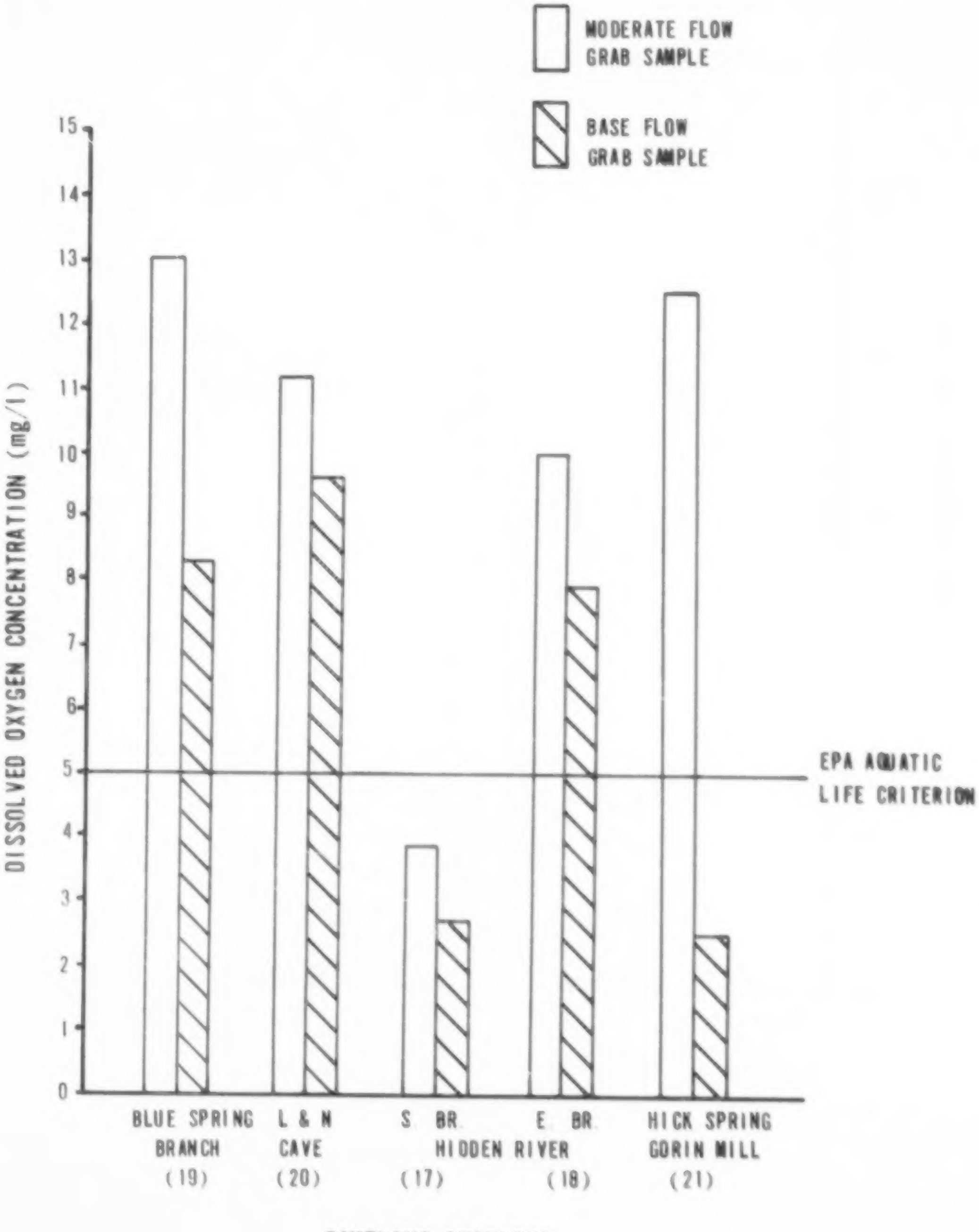
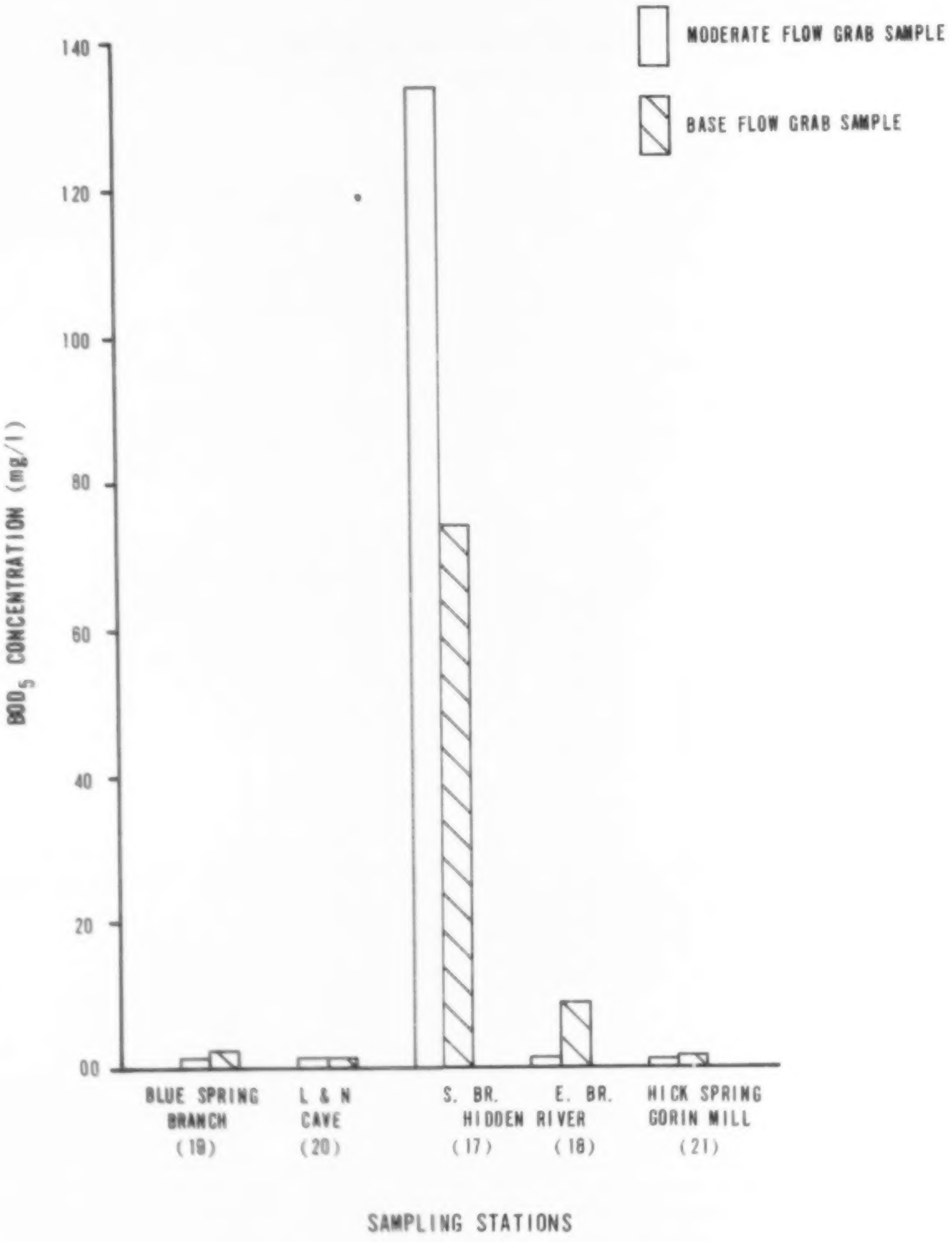


FIGURE I-24

BOD_5 CONCENTRATIONS IN HIDDEN RIVER BASIN



not be greatly effected. Still another explanation of the observed BOD$_5$ and D.O. values is that as the East Branch waters flow through the rock formations into the Hidden River Cave entrance, they are reaerated.

The BOD$_5$ value of 9 mg/l measured in the low flow East Branch sample is higher than anticipated. Assuming all the Cave City wastewater (50 mg/l BOD$_5$ and .236 mg/l) mixed with the East Branch (2 mg/l BOD$_5$ and 6 CFS) immediately upstream from the sampling point the anticipated BOD$_5$ concentration is only approximately 5 mg/l. This assumes no degradation of Cave City wastes between Cave City and Hidden River Cave, which is unlikely. BOD$_5$ values less than 10 mg/l are not considered to be highly accurate, and therefore, based on one sample there is little or no difference between 5 and 9 mg/l.

The conclusions resulting from BOD$_5$ and D.O. concentrations observed in the East Branch of Hidden River Cave are as follows:

1) The BOD$_5$ concentration is higher than generally found in unpolluted waters in the cave area.

2) The simultaneous occurance of "high" BOD$_5$ and D.O. concentrations may be due to organic pollution entering the East Branch immediately upstream from the sampling point or the result of aeration of the stream as it flows into Hidden River Cave.

Ammonia Nitrogen (Figure II-25) - Ammonia nitrogen levels during both moderate and base flow conditions were significantly higher at the East Branch and South Branch of Hidden River Cave than in the unpolluted waters of Blue Spring Branch and L&N Cave. In addition, at Hick Spring and Gorin Mill Spring ammonia nitrogen levels are similar to Blue Spring Branch and L&N cave, indicating the effects of dilution. Because of temperature and pH conditions, only during base flow in South Branch Hidden River Cave were toxic levels of ammonia detected.

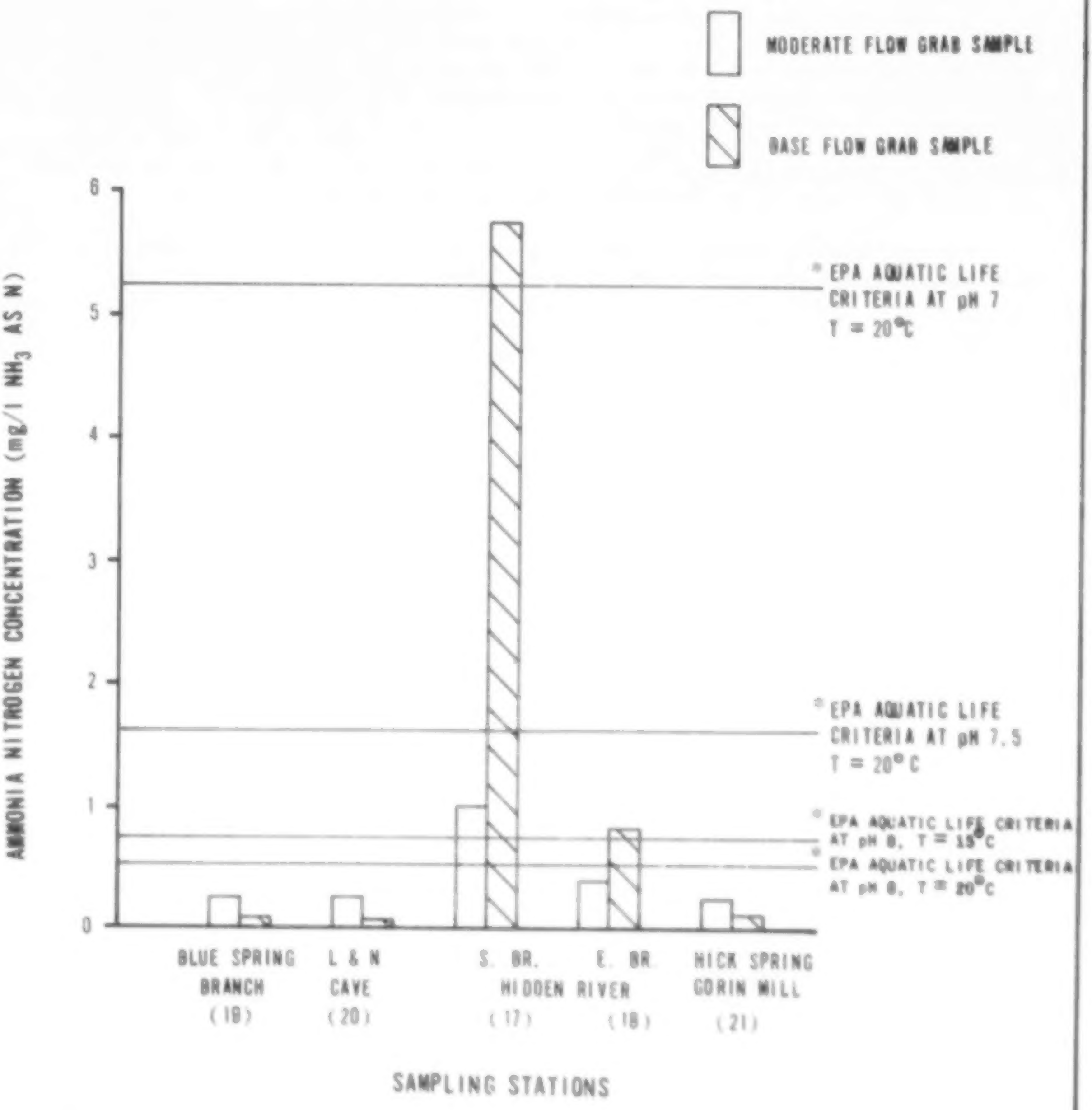
Nitrate Nitrogen (Figure I-26) - The level of nitrate nitrogen found in the waters of L&N cave during base flow conditions were significantly higher than any other sampling station and is at the drinking water limit of 10 mg/l. This appears to indicate a stabilized source of pollution or perhaps a spill of some fertilizer. Other nitrate nitrogen levels are within the range found in the Turnhole Spring Basin.

Total Dissolved Solids (TDS) (Figure I-27) Chloride (Figure I-28) and Sulfate (Figure I-29) - These parameters are not considered to be important indicators for assessing water quality in the Hidden River Basin since no significant sources were sampled other than the Horse Cave treatment facility. For this reason, no analyses for chloride or sulfate were performed for the base flow samples. TDS levels under both base flow and moderate flow conditions meet drinking water criteria, with the exception of South Branch Hidden River Cave.

Total Chromium (Figure I-30) - Chromium concentrations in South Branch Hidden River Cave during base flow conditions were found to be substantially less than during moderate flow. This is primarily a result of the reduced chromium loading to the Horse Cave treatment plant by Ken Dec, Inc. However, even with improvements, total chromium levels detected in the South Branch are still toxic to aquatic life. Chromium levels measured at all other points

FIGURE I-25

AMMONIA NITROGEN CONCENTRATIONS IN HIDDEN RIVER BASIN



*BASED ON .02 mg/l UN-IONIZED AMMONIA

FIGURE I-26

NITRATE NITROGEN CONCENTRATIONS
IN THE HIDDEN RIVER BASIN

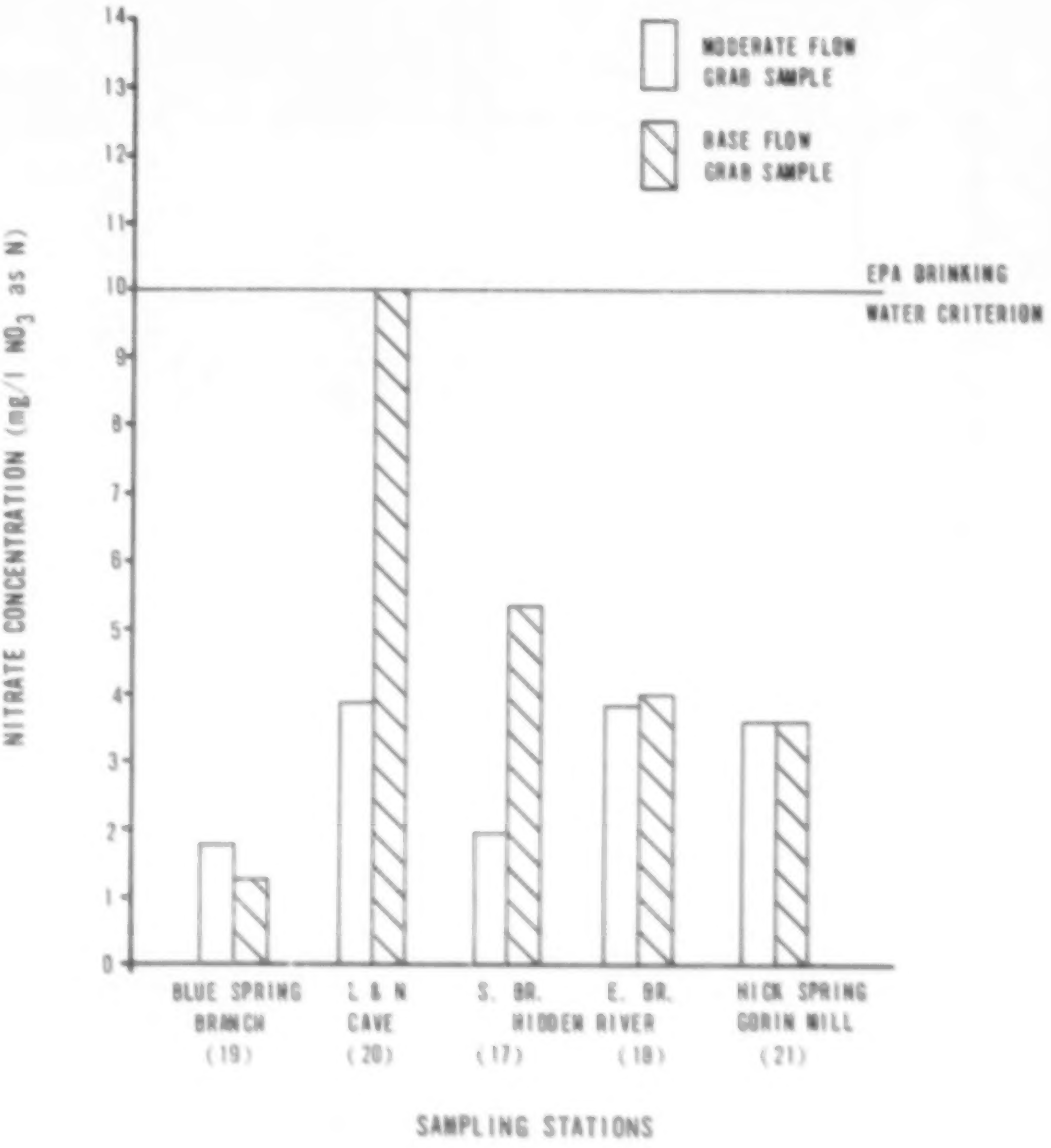


FIGURE I-27

TOTAL DISSOLVED SOLIDS CONCENTRATIONS IN HIDDEN RIVER BASIN

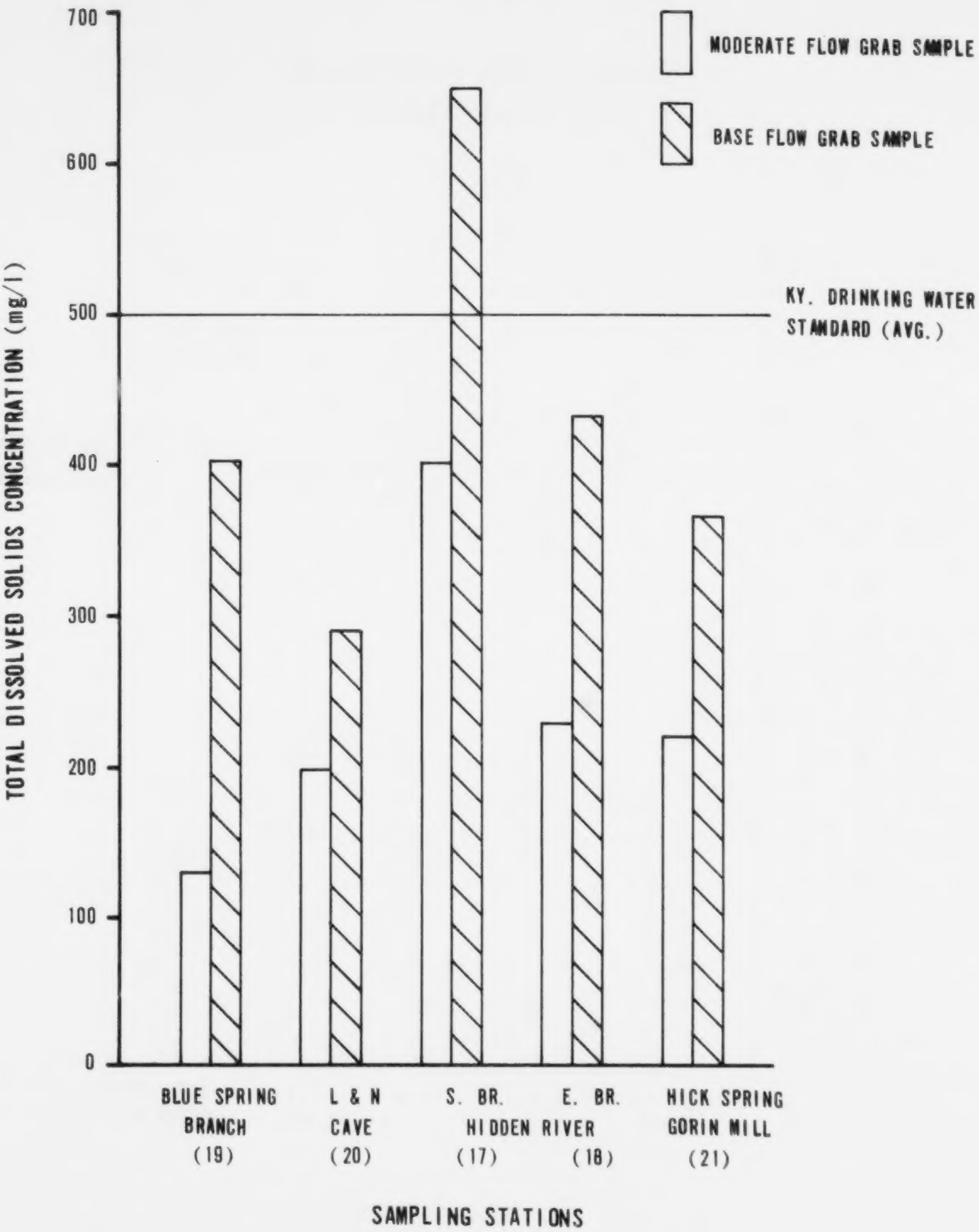
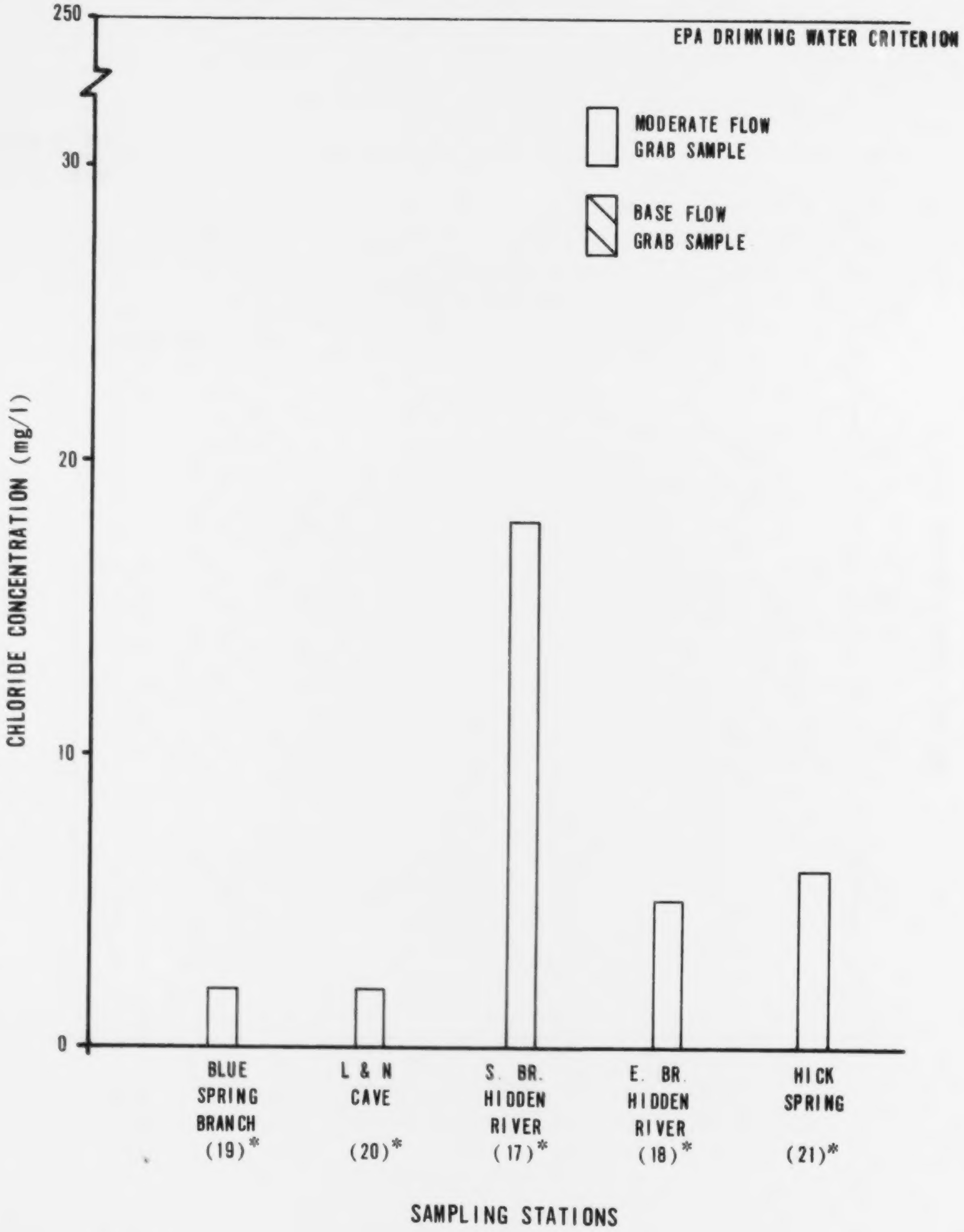


FIGURE I-28

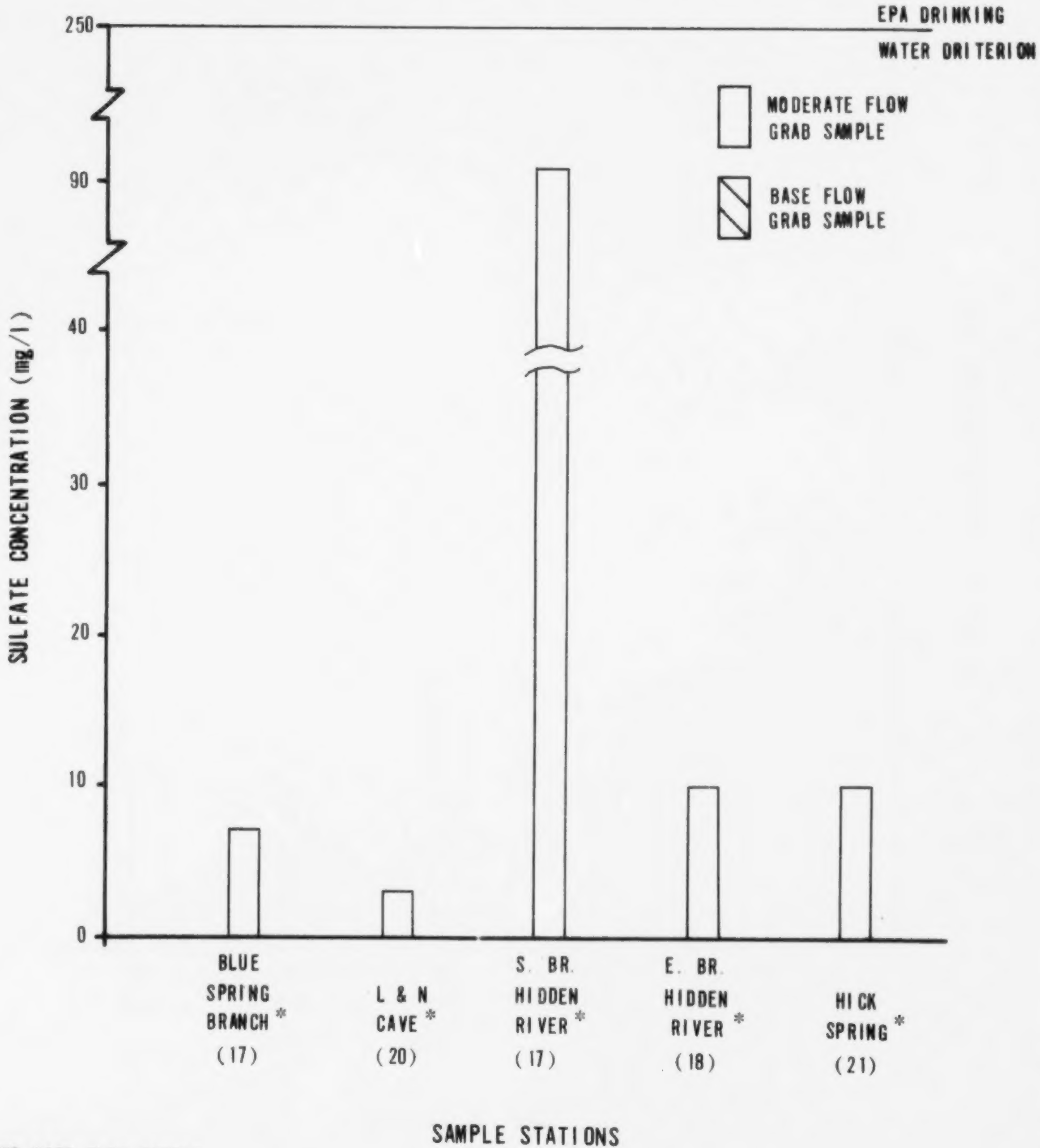
CHLORIDE CONCENTRATIONS IN HIDDEN RIVER BASIN



* NO BASE FLOW SAMPLE

FIGURE I-29

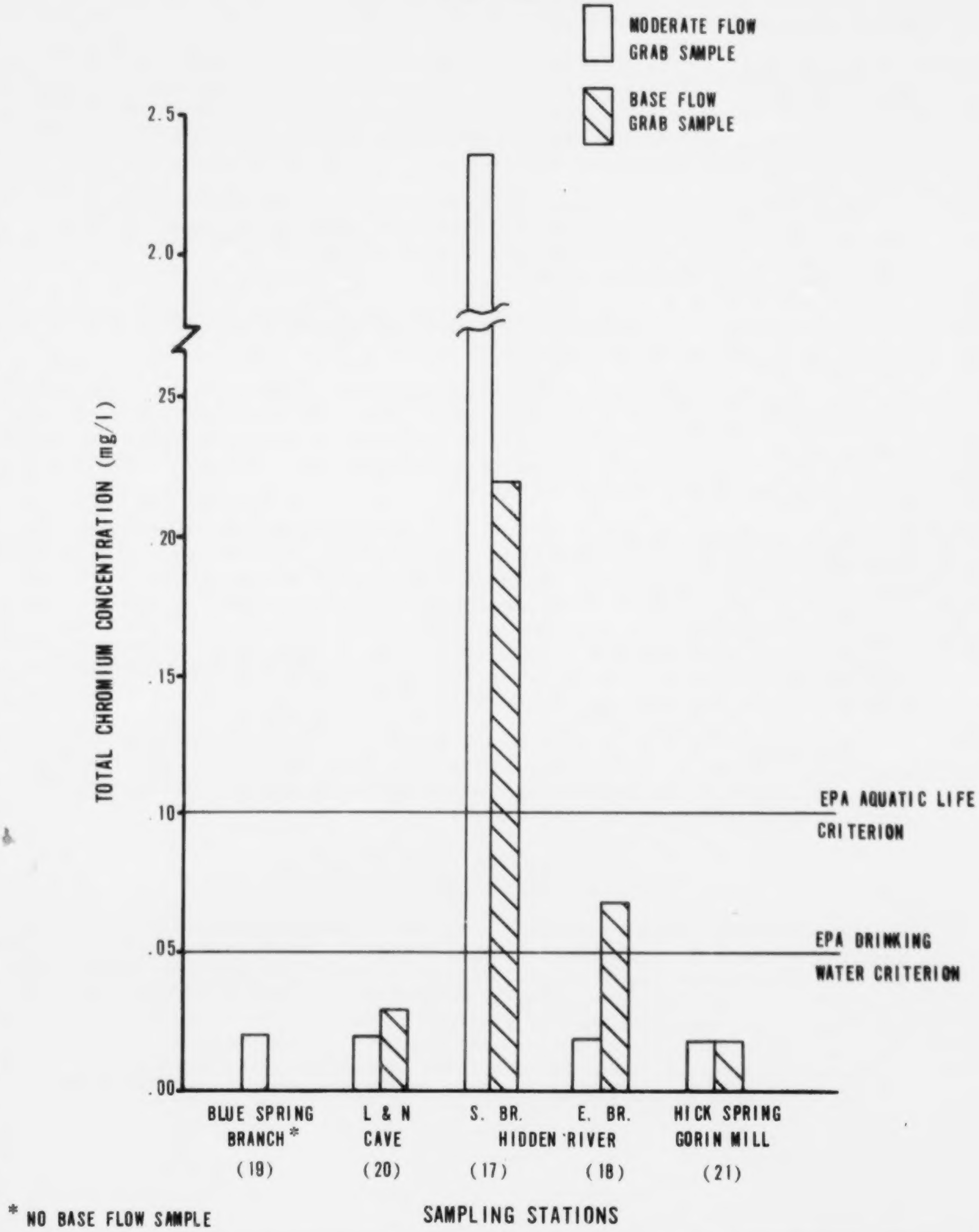
SULFATE CONCENTRATIONS IN HIDDEN RIVER BASIN



* NO BASE FLOW SAMPLE

FIGURE I-30

TOTAL CHROMIUM CONCENTRATIONS IN HIDDEN RIVER BASIN



sampled in the Hidden River Cave Basin are within the aquatic life criterion. One significant result of sampling is that despite the relatively large contribution of chromium from Horse Cave, chromium levels at Hick Spring and Gorin Mill Spring are similar to background concentrations at L&N Cave, indicating that the South Branch of Hidden River Cave is diluted sufficiently to significantly reduce metals concentrations at the springs.

Nickel (Figure I-31) - Nickel concentrations in Hidden River Cave South Branch, as measured during base flow sampling, are in the range toxic to aquatic life. As in the case of chromium, nickel concentrations detected at Hick Spring and Gorin Mill Spring indicate that high concentrations in South Branch are diluted to near background levels.

Copper (Figure I-32 - Cooper concentrations in South Branch Hidden River Cave, as measured during moderate and base flow sampling are toxic to aquatic life. Copper concentrations detected at Hick Spring and Gorin Mill Spring are within the aquatic life criteria.

Iron - Iron is not considered a significant parameter for assessing water quality in the Hidden River Basin.

Zinc Figure I-33) - Zinc concentrations in the South Branch of Hidden River Cave measured during base flow and moderate flow conditions, are toxic to some aquatic life. However, zinc concentrations measured during moderate flow conditions at Blue Spring Branch and L&N Cave indicate that these toxic levels may occur naturally during periods of runoff.

Fecal Coliform (Figure I-34) - Fecal coliform densities measured during baseflow and moderate flow conditions indicate that, with the exception of Hidden River Cave, waters sampled in the Hidden River basin are suitable for bathing purposes and do not appear to be subject to significant human or animal pollution. Coliform densities measured in Hidden River Cave South Branch during moderate flow conditions are considered low due to high concentrations of metals. High concentrations of fecal coliform levels detected in Hidden River Cave during base flow conditions are typical of polluted waters.

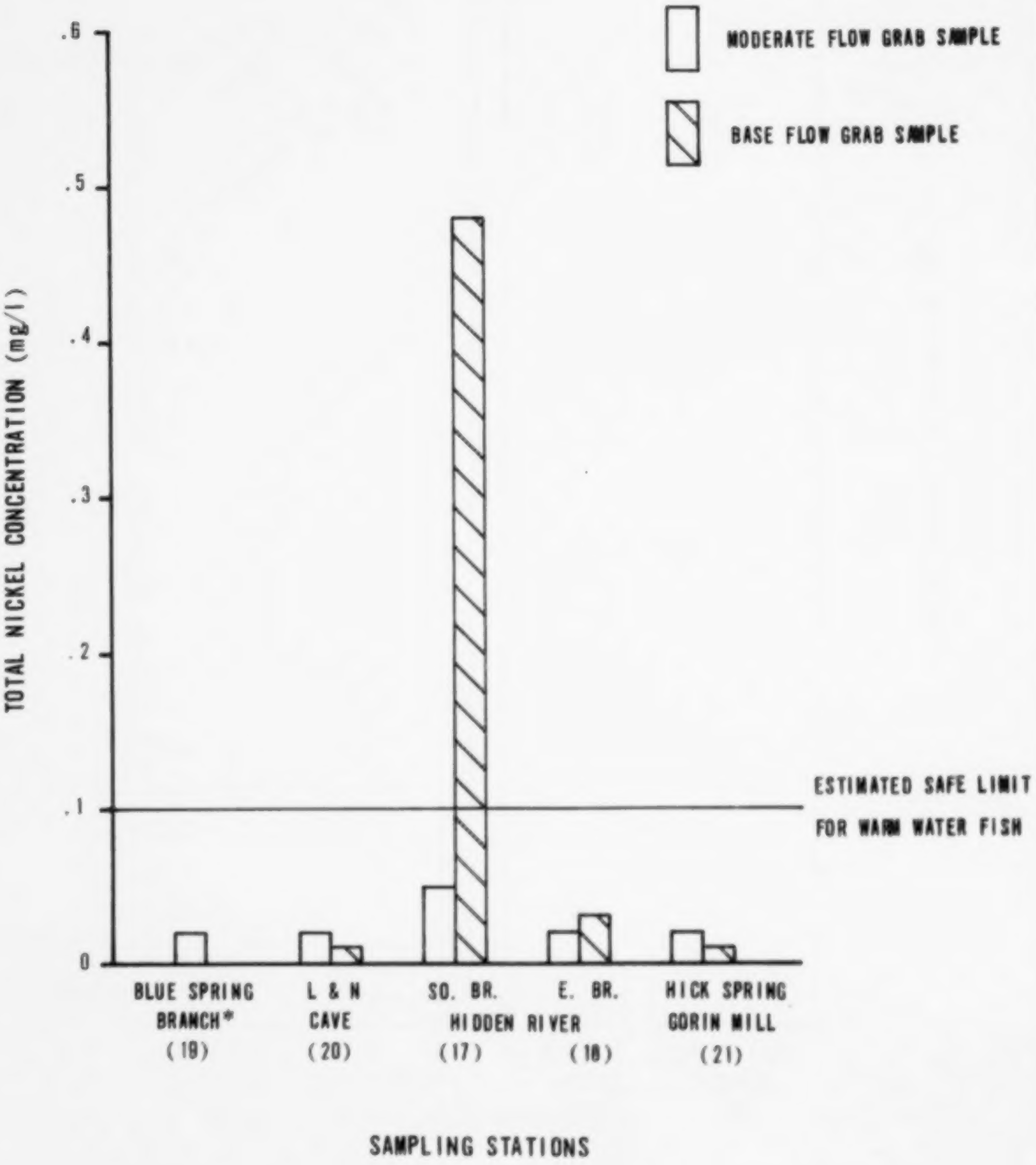
Pesticides - Waters of Blue Spring Branch, which drains an agricultural area, were sampled for pesticides during base flow conditions. Results from a pesticide scan for Lindane, Endrin, Methoxychlor and Toxaphene indicate concentrations were less than detectable limits.

General Water Quality
Turnhole Spring, Hidden River and Echo-Styx Basins

Results from the one-time grab sampling program indicate that pollution problems in Turnhole Spring Basin and Hidden River Basin appear to be localized. The only significant source of pollution detected in the Turnhole Spring basin is the Phantom Sulfur spring. Any adverse effects on water quality appear to be confined to the immediate area of the spring. In the Hidden River Basin, while both Cave City and Horse Cave discharge wastewater treatment plant effluent to the subsurface waters, evidence of adverse effects on water quality observed in Hidden River Cave during the groundwater sampling program appear to be primarily

FIGURE I-31

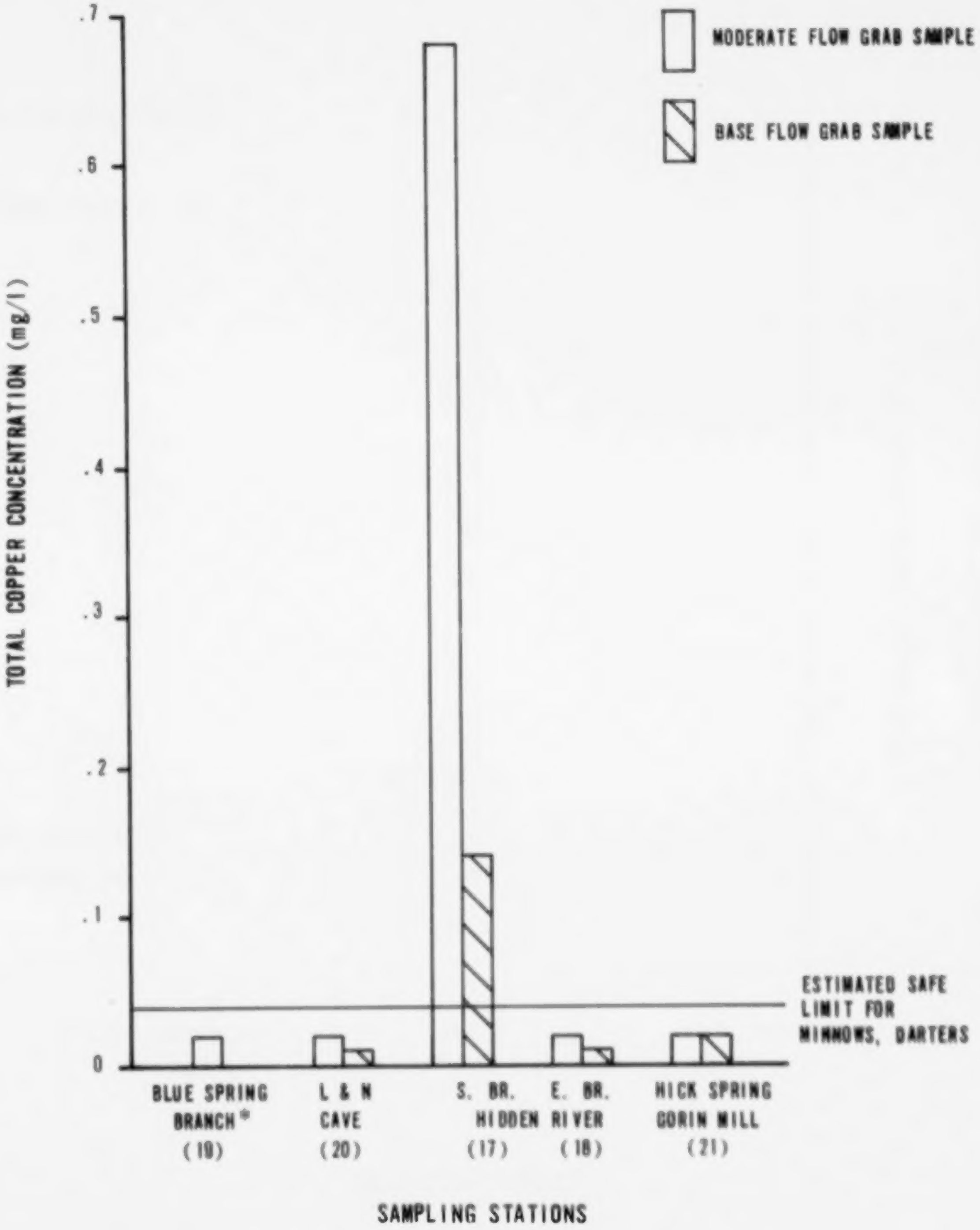
NICKEL CONCENTRATIONS IN HIDDEN RIVER BASIN



* NO BASE FLOW SAMPLE

FIGURE I-32

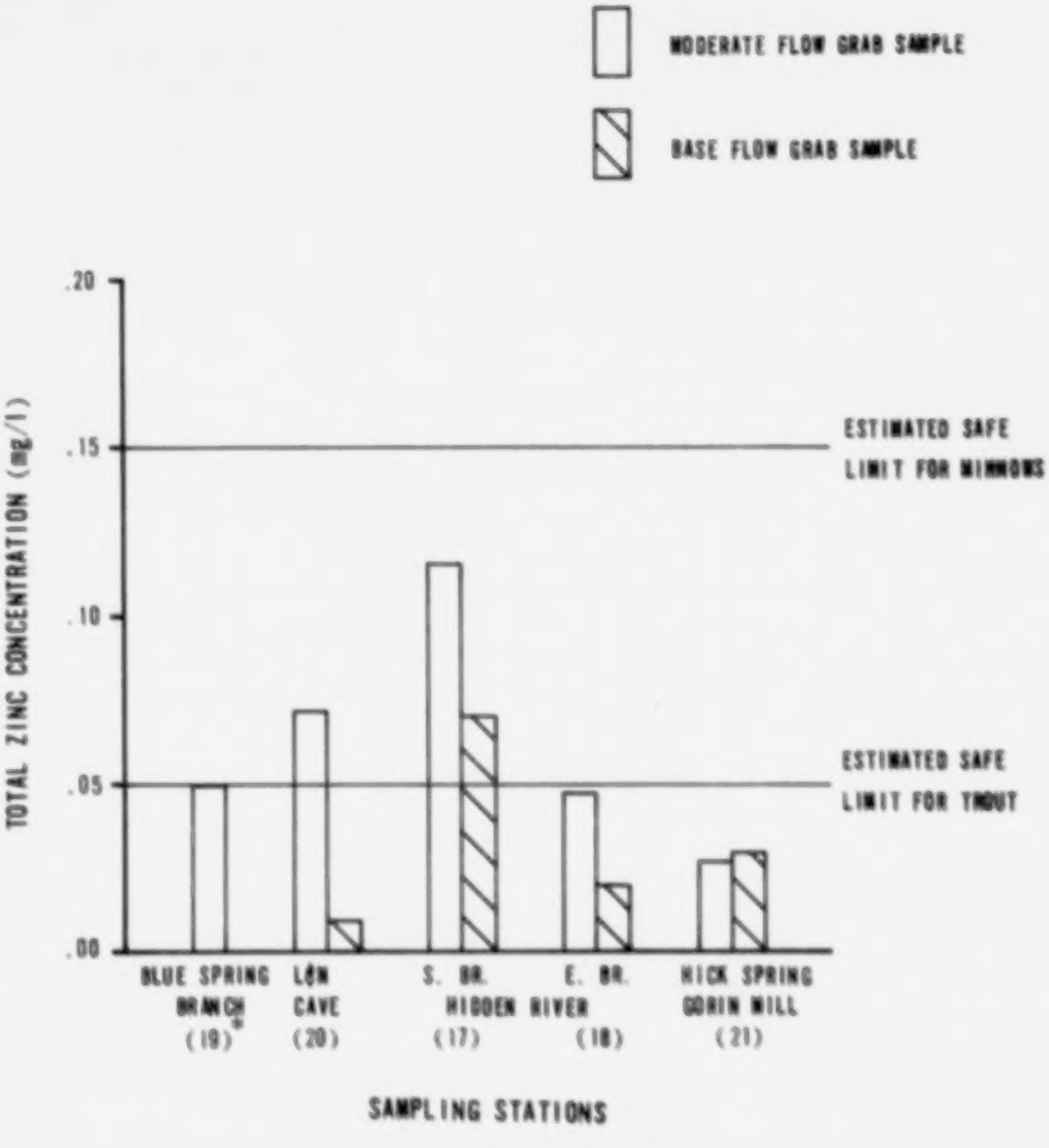
TOTAL COPPER CONCENTRATIONS IN HIDDEN RIVER BASIN



* NO BASE FLOW SAMPLE

FIGURE I-33

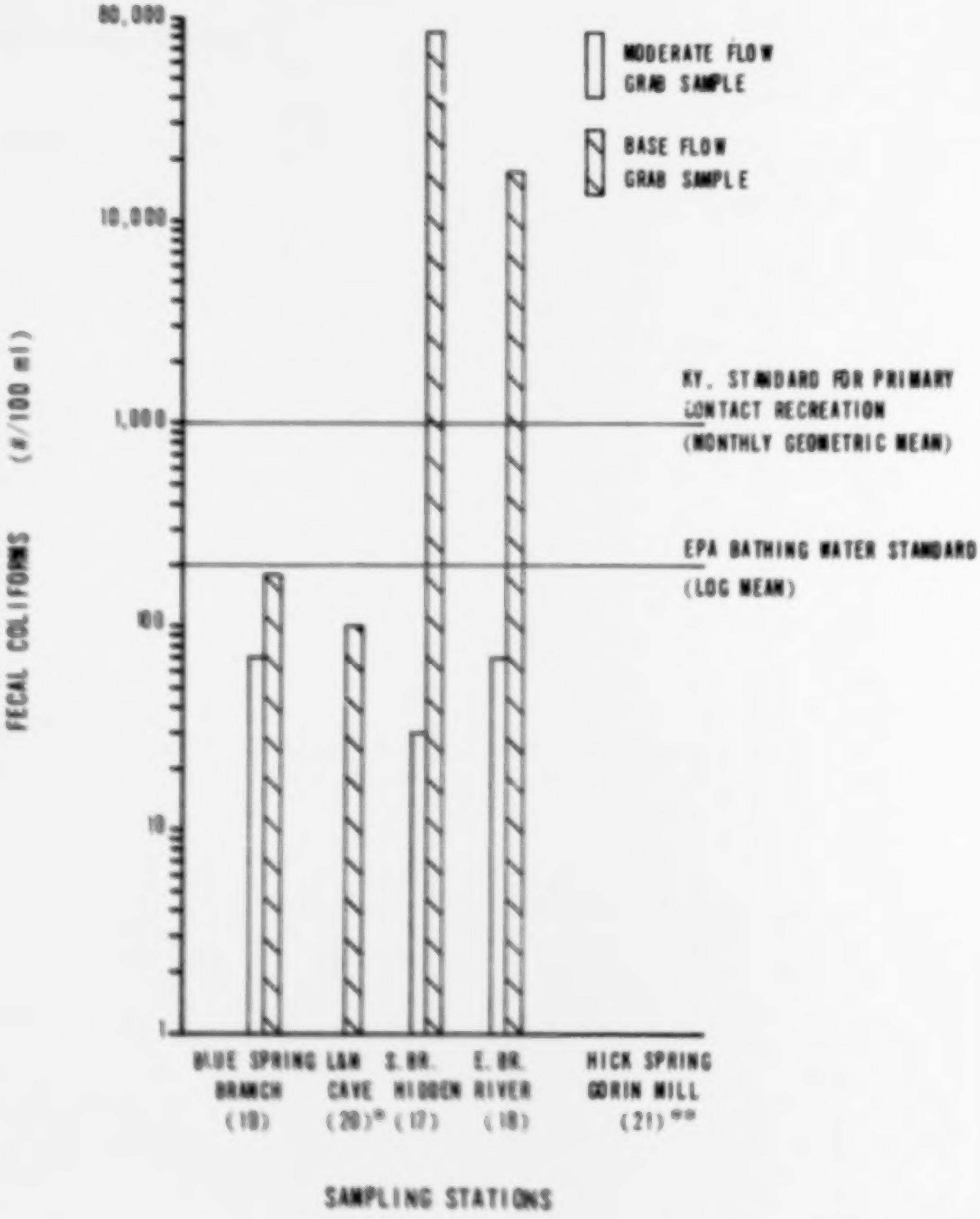
TOTAL ZINC CONCENTRATIONS IN HIDDEN RIVER BASIN



* NO BASE FLOW SAMPLE

FIGURE I-34

FECAL COLIFORM DENSITIES IN HIDDEN RIVER BASIN



* NO MODERATE FLOW SAMPLE
** 0 FECAL COLIFORM

attributable to the Horse Cave wastewater discharge[1]. However, it appears likely that some water quality problems, impossible to detect, may exist in the subsurface stream between Cave City and the East Branch of Hidden River Cave. In addition, fecal coliform levels in the East Branch are extremely high, probably due to the Cave City discharge.

The toxic metals and heavy organic loadings resulting from the Horse Cave discharge have severely degraded water quality in the South Branch. However, the extent of water quality problems associated with the Horse Cave discharge is unknown. Even though the data indicate that pollutants are well diluted downstream in the Hidden River system, low D.O. levels observed in Gorin Mill Spring also show that the effects the Horse Cave wastewater discharge, combined with a much smaller organic loading from the Cave City discharge, may extend far downstream from the confluence of the East and South Branches. Therefore, while pollution problems caused by toxic metals may be localized in South Branch and the vicinity immediately downstream, effects from organic pollution may be more widespread depending on conditions for reaeration in the Hidden River Cave System.

In order to assess the general water quality in the Turnhole Spring, Hidden River and Echo-Styx basins, samples of the final basin discharges to the Green River were collected (during both moderate and base flow) at Cedar Sink/Owl Cave, Hick Spring/Gorin Mill Spring and Echo River Spring, respectively. Each of these samples provides a composite of all the water in each basin.

The results of water quality analyses for important water quality parameters are illustrated in Figures I-35 and I-41. With only two exceptions water quality in these waters, based on these results, meets and/or exceeds the criteria for the use classifications of aquatic life, drinking water supply and bathing. One exception is the zinc concentration, recorded at moderate flow at Cedar Sink. The zinc concentrations, apparently a function of runoff, exceed the toxic limit for some trout. However, this may not be an appropriate criterion for the blind cave fish. Since the aquatic life in the area appear to be unaffected, this temporary higher level of zinc is considered acceptable for aquatic life. (See discussion of heavy metals pg. (I-71). The other exception is somewhat more serious. The D.O. measured at Gorin Mill Spring is

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[1] Water Quality degradation in South Branch Hidden River Cave is due almost entirely to the Horse Cave wastewater discharge. Low D.O. levels downstream of the confluence of the East and South Branches may be partly due to the organic loading contributed by Cave City which enters Hidden River Cave via the East Branch. However, from operating data and base flow samples organic load to Hidden River Cave contributed by Cave City appears to be only approximately 15% of the total load under present conditions.

Horse Cave BOD_5 Loading = (265 mg/l BOD_5) x (.34 mgd) x 8.34 = 750 lbs/day

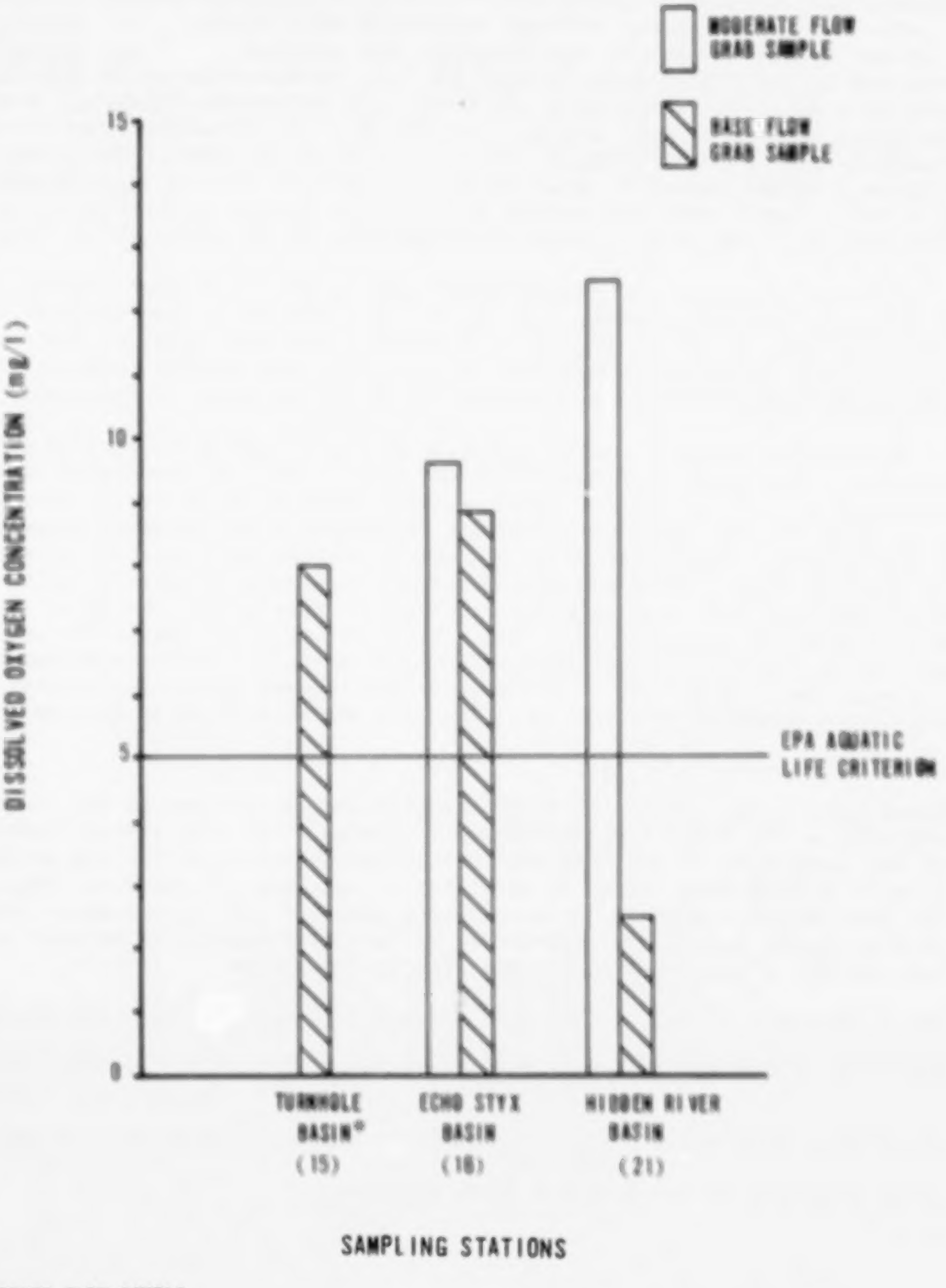
Cave City BOD_5 Loading = (65 mg/l BOD_5) x (.236mgd) x 8.34 = 128 lbs/day

Total = 878 lbs/day

Cave City contribution = $\frac{128}{878}$ = .15; this assumes no degradation of BOD_5 prior to mixing of the East and South Branches.

FIGURE I-35

DISSOLVED OXYGEN CONCENTRATIONS IN THE FINAL BASIN DISCHARGES TO THE GREEN RIVER



* NO MODERATE FLOW SAMPLE

FIGURE I-36

BOD$_5$ CONCENTRATIONS IN THE FINAL
BASIN DISCHARGES TO THE GREEN RIVER

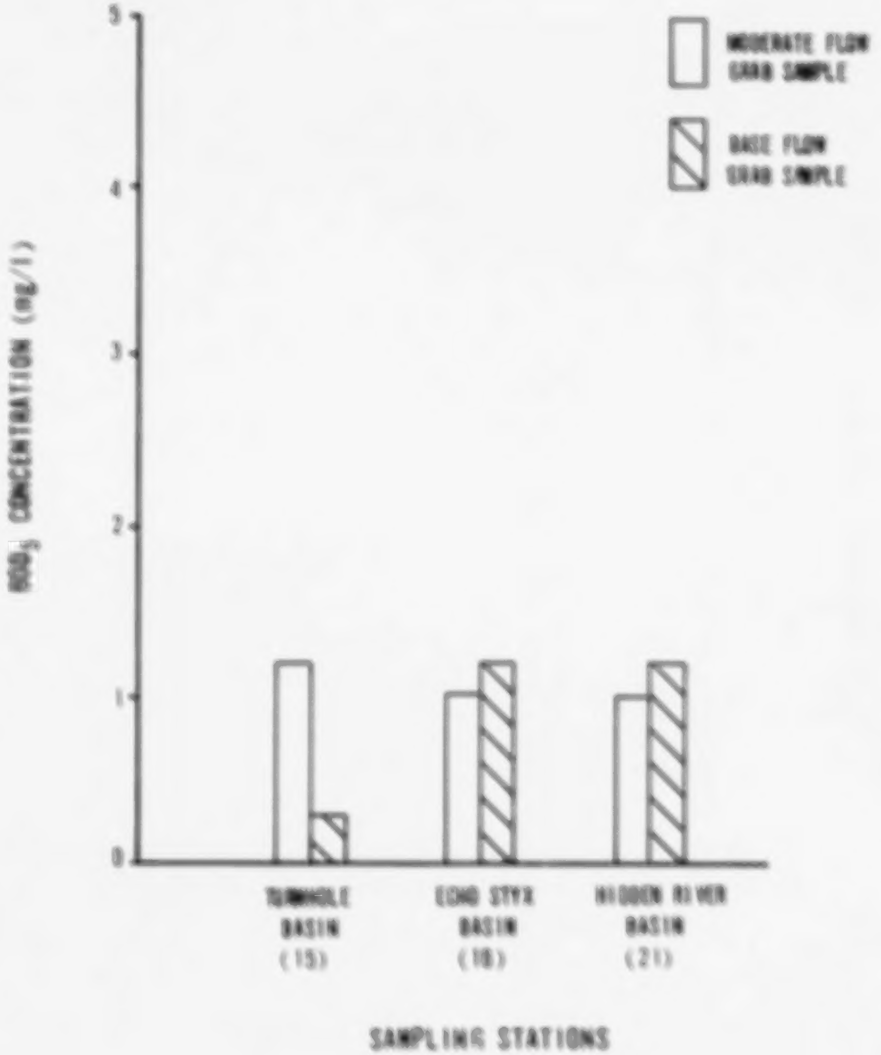


FIGURE I-37

FECAL COLIFORM DENSITIES IN THE
FINAL BASIN DISCHARGES TO THE GREEN RIVER

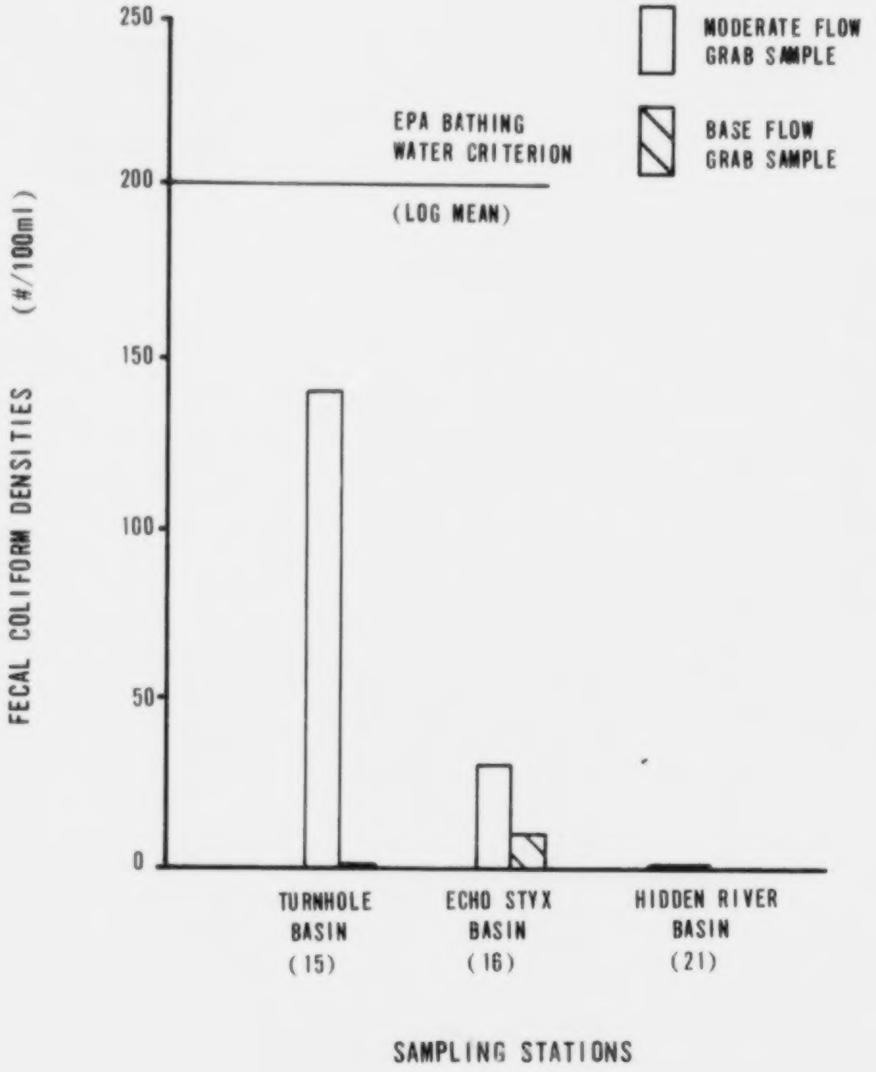
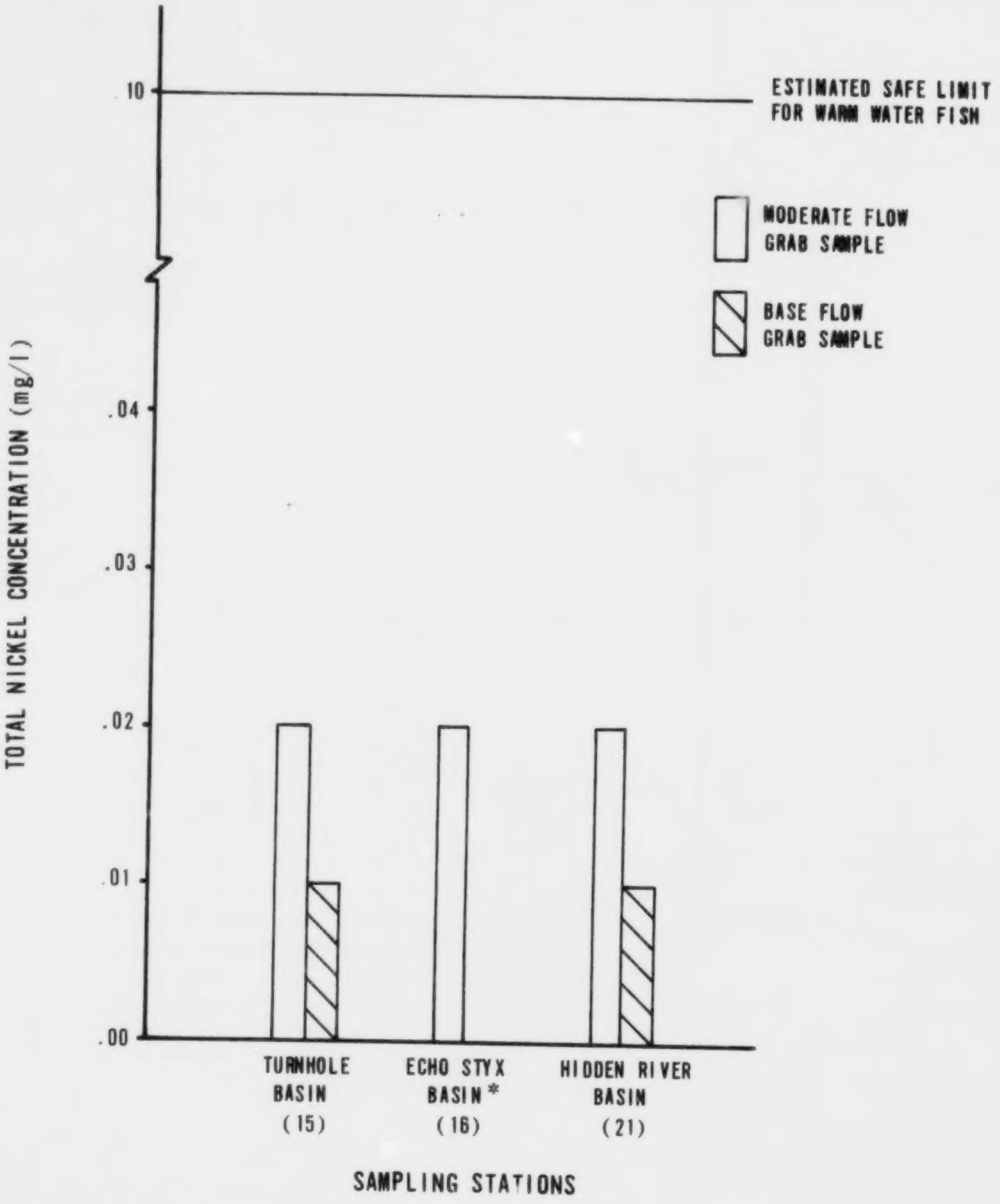


FIGURE I-38

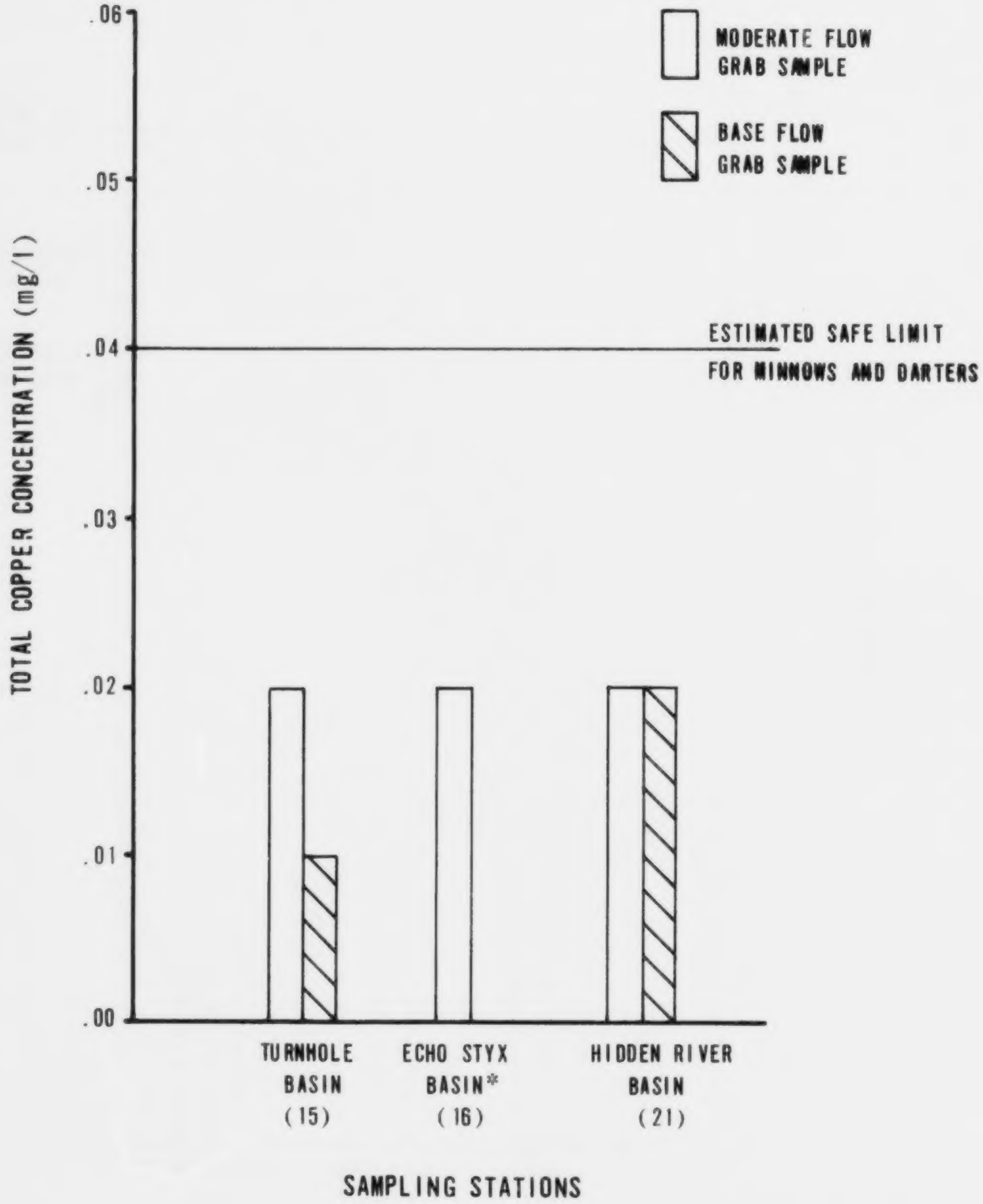
TOTAL NICKEL CONCENTRATIONS IN THE FINAL BASIN DISCHARGES TO THE GREEN RIVER



* NO BASE FLOW SAMPLE

FIGURE I-39

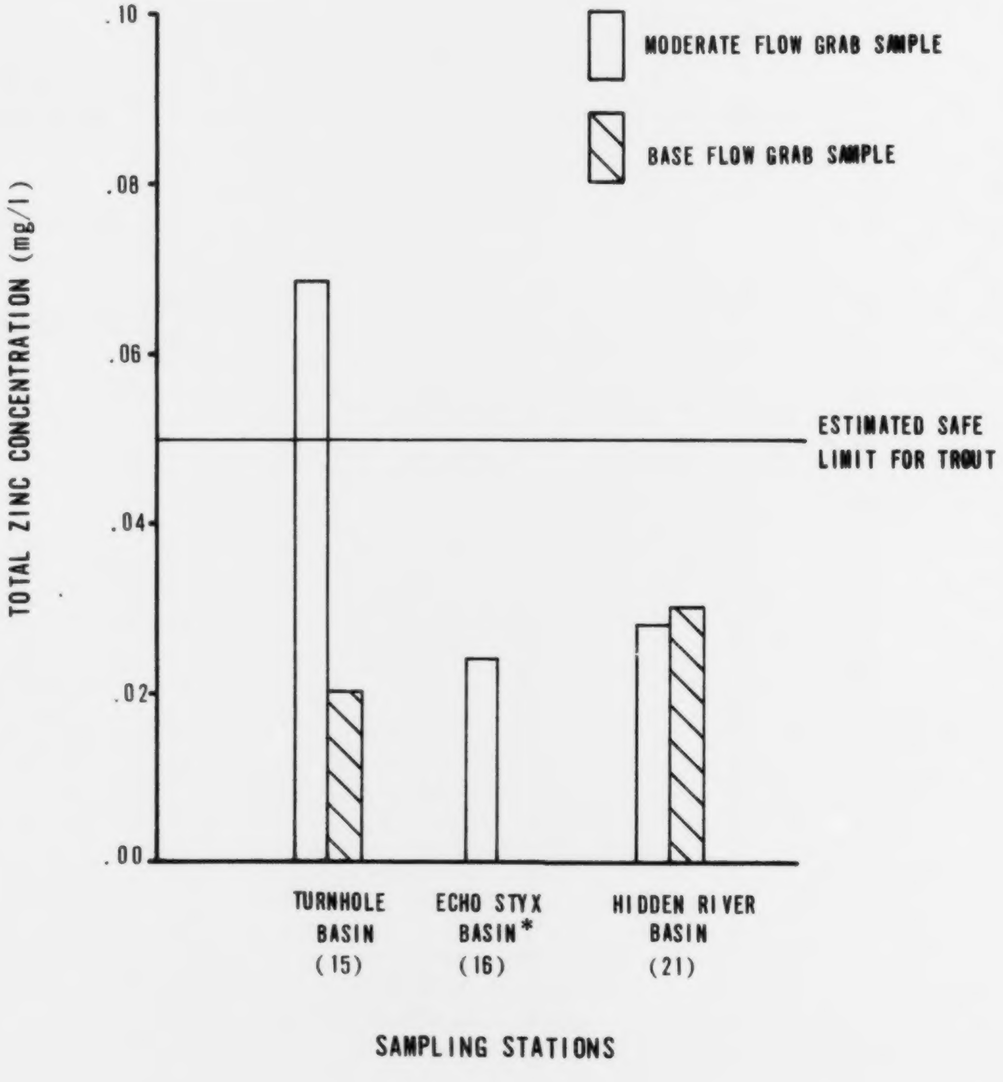
TOTAL COPPER CONCENTRATIONS IN THE
FINAL BASIN DISCHARGES TO THE GREEN RIVER



* NO BASE FLOW SAMPLE

FIGURE I-40

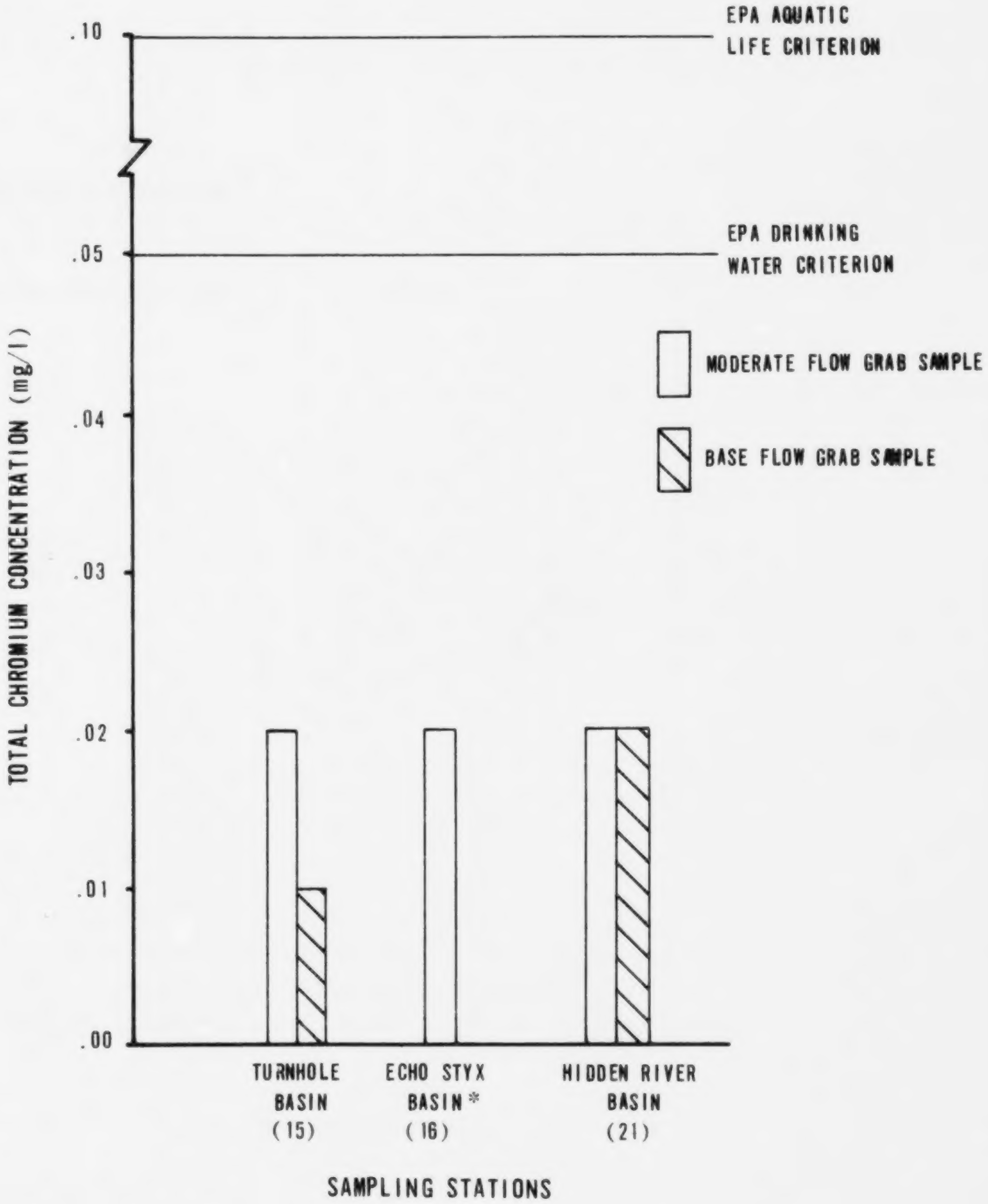
TOTAL ZINC CONCENTRATIONS IN THE
FINAL BASIN DISCHARGES TO THE GREEN RIVER



* NO BASE FLOW SAMPLE

FIGURE I-41

TOTAL CHROMIUM CONCENTRATIONS IN THE FINAL BASIN DISCHARGES TO THE GREEN RIVER



* NO BASE FLOW SAMPLE

unacceptable for maintaining aquatic life. Since Gorin Mill Spring is the major discharge from the Hidden River Cave system, this may indicate that most of the waters of the Cave system are adversely affected by the organic loading from Horse Cave, combined with a smaller loading from Cave City, and are not capable of supporting aquatic life. It appears that since pollutants such as heavy metals are so diluted at Gorin Mill Spring and the BOD_5 concentration at the spring is also at background levels, the D.O. problem is a result of a lack of re-aeration in the Cave system as previously discussed. This assumption is supported by the findings that D.O. concentrations at Hick Spring during base flow conditions were acceptable for maintaining aquatic life (figure I-42), indicating that waters of Hick Spring had been re-aerated before discharge to the Green River.

Based on these composite samples, general water quality in both the Echo-Styx and Turnhole Spring Basins appears to be excellent. Furthermore, if organic pollutants discharged to the Hidden River Basin were substantially reduced, it appears that the general water quality in this basin would be acceptable for maintaining aquatic life. (See discussion of heavy metals pg (I-71).

Base Flow Extended Sampling Program

The base flow extended sampling program was developed to monitor changes in water quality at selected locations during critical baseflow conditions. The sampling stations included in the extended sampling are as follows:

Turnhole Spring Basin	- Apple Grove drainage (#4) - Mill Hole (#14)
Hidden River Basin	- L&N Cave (#20) - Blue Spring Branch (#19) - East Branch Hidden River Cave (#18) - South Branch Hidden River Cave (#17) - Gorin Mill Spring (#21)

In waters that do not receive constant waste discharges but are more affected by pollution due to runoff conditions, the most critical period for water quality may not necessarily occur at the lowest stream flow but after a rainfall when runoff carries pollutants to streams and then subsides, leaving organic materials deposited in the stream beds to decay as the stream returns to base flow conditions. This type of pollution may be indicated by a temporary rise in nitrogen and a decrease in dissolved oxygen levels. The intention of the extended base flow sampling program is to detect these types of changes as well as expand the one-time grab sample data.

Figures I-43 to I-64 present data gathered during the program for dissolved oxygen, nitrogen forms, metals and conductivity.

Dissolved Oxygen (Figure I-43 to I-48) - Of the parameters sampled during the program, D.O. is the most important and is likely to be the best indicator of organic pollution. With the exception of Hidden River Cave, South Branch and Gorin Mill Spring, D.O. levels at all stream sampling locations were found to be consistently greater than 5 mg/l, the aquatic life criterion. In addition, even though D.O.'s were reasonably constant at each site, some fluctuation was evident at all locations. At several sites it appears to be attributable to

FIGURE I-42

BASE FLOW DISSOLVED OXYGEN CONCENTRATIONS
AT HICK SPRING AND GORIN MILL SPRING

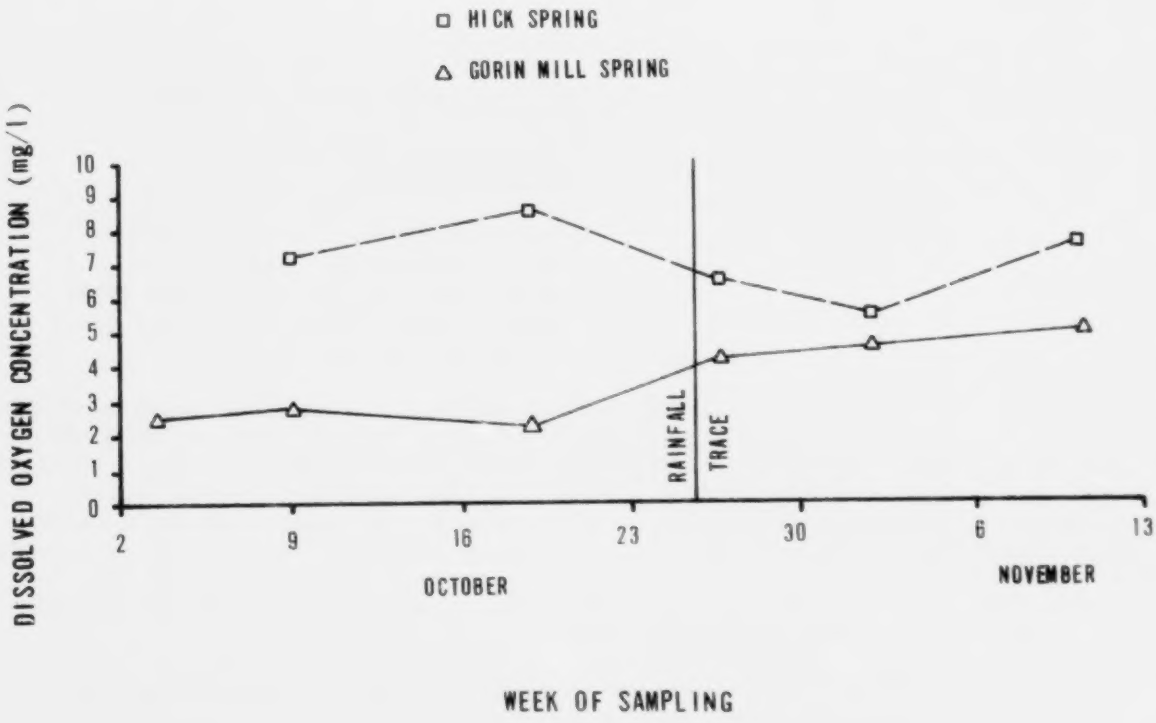


FIGURE I-43

DISSOLVED OXYGEN CONCENTRATIONS DURING SEPT.-NOV. 1978
AT APPLE GROVE DRAINAGE (#4)

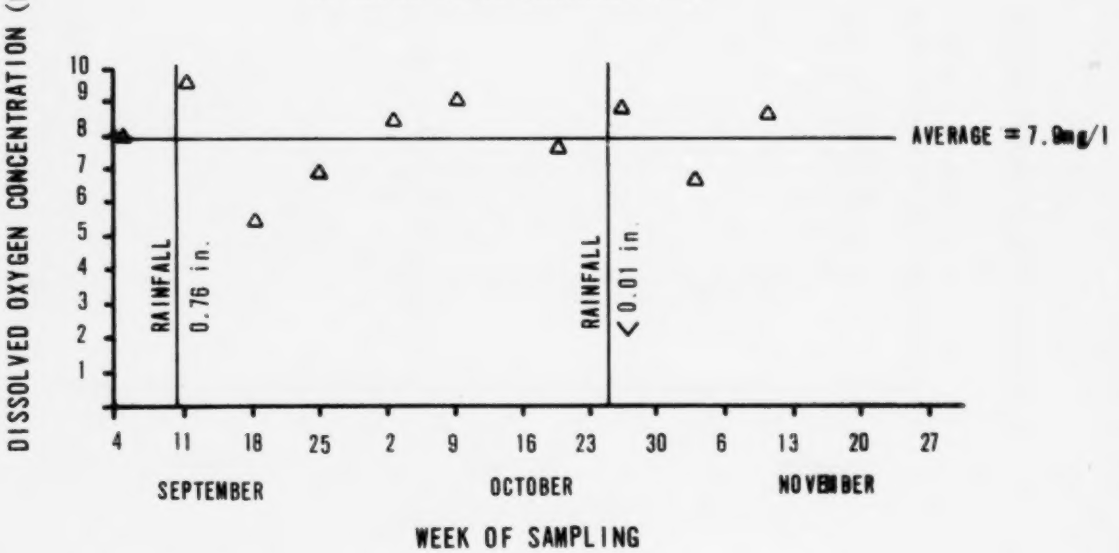


FIGURE I-44
DISSOLVED OXYGEN CONCENTRATIONS DURING SEPT.-NOV. 1978
AT MILL HOLE (#14)

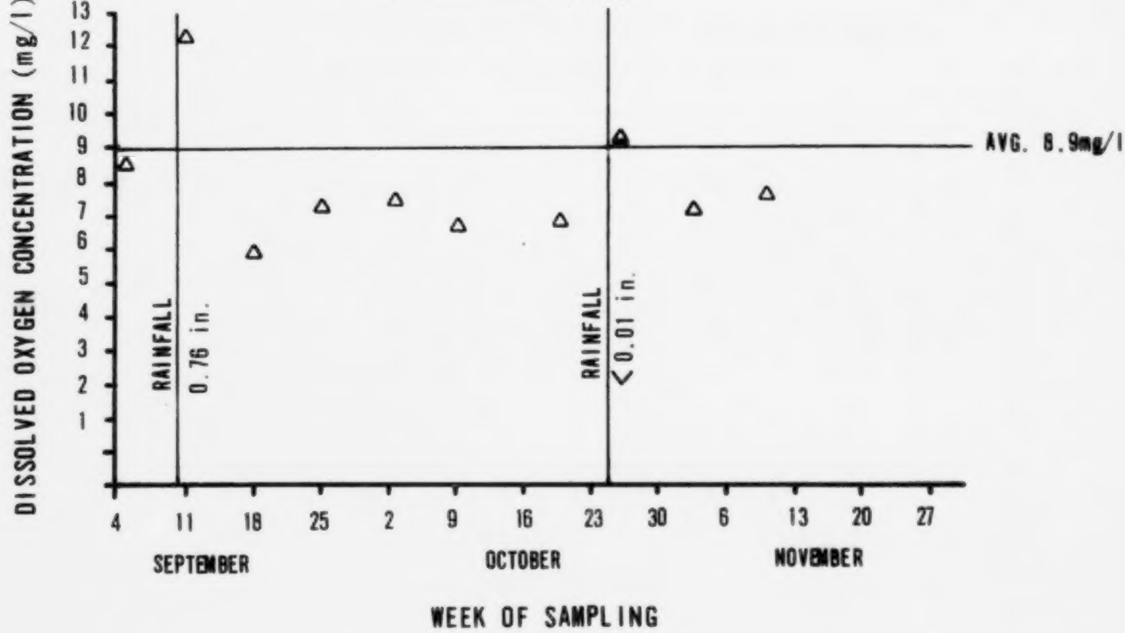


FIGURE I-45

DISSOLVED OXYGEN CONCENTRATIONS DURING SEPT.-NOV. 1978
AT SOUTH BRANCH HIDDEN RIVER (#17)

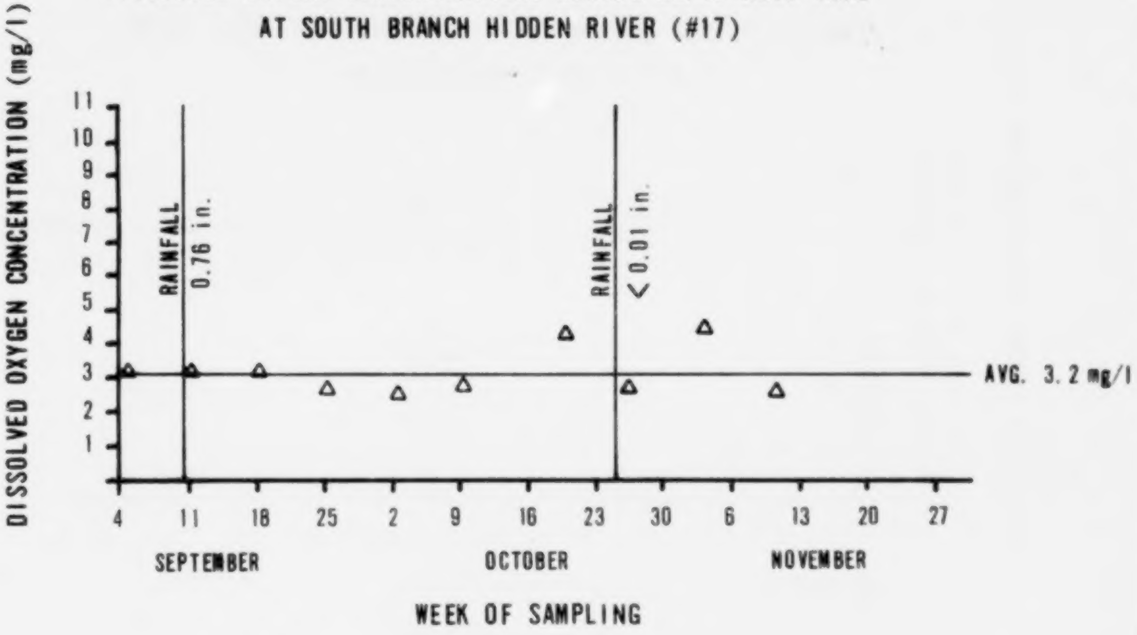


FIGURE I-46

DISSOLVED OXYGEN CONCENTRATIONS DURING SEPT.-NOV. 1978
AT EAST BRANCH HIDDEN RIVER CAVE (#18)

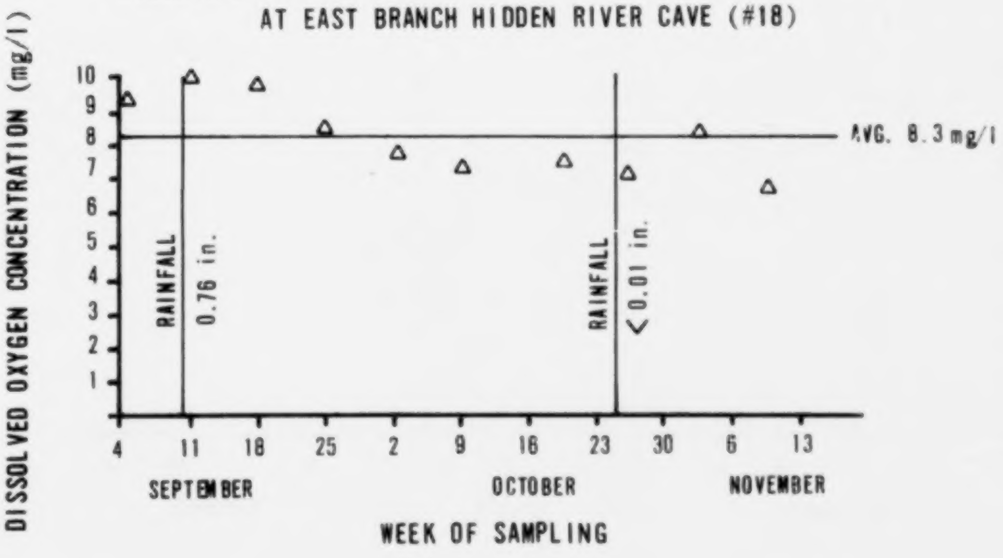


FIGURE I-47

DISSOLVED OXYGEN CONCENTRATIONS DURING SEPT.-NOV. 1978
AT BLUE SPRING BRANCH (#19)

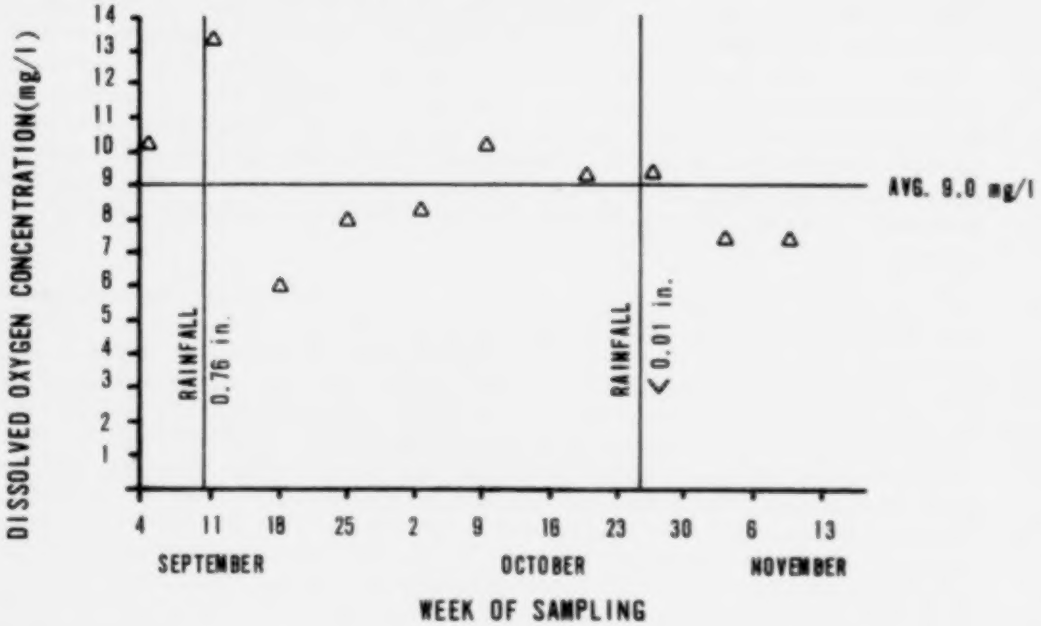
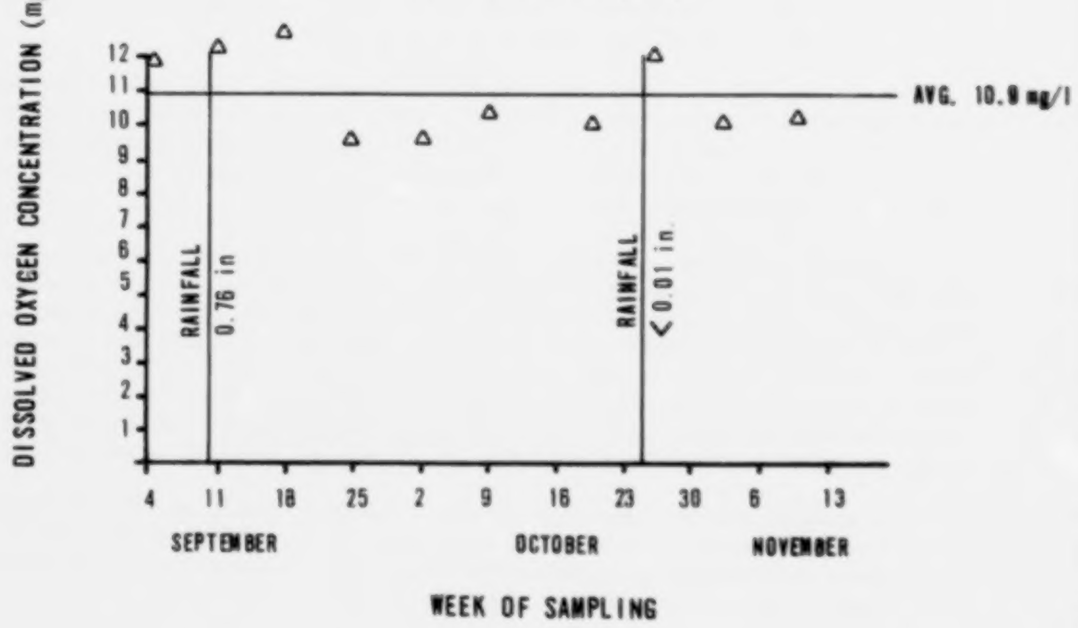


FIGURE I-48

DISSOLVED OXYGEN CONCENTRATIONS DURING SEPT.-NOV. 1978
AT L & N CAVE (#20)



rainfall effects. These are Apple Grove drainage, Mill Hole, and Blue Spring Branch. Rainfall (.76 inches) before the sample of September 11, 1978 first appears to drive oxygen levels up temporarily (high reaeration due to rapid flow). In the following weeks dissolved oxygen drops and then recovers, perhaps indicating decay, stabilization then reaeration. After a small rainfall (trace, <0.01 inches) just before the sample of the week of October 23, 1975, D.O.levels increase then fall in subsequent samples. However, such a small rainfall is not considered to be significant. (See Figures I-43-I-48). Dissolved oxygen data, at least for the first rainfall event, appears to indicate small adverse effects due to runoff; however, at no sampling station did D.O. levels drop below 5.0 mg/l. The lowest D.O. reading (5.6 mg/l) was found at Apple Grove drainage the week following the first rain. This condition is not unexpected since the Apple Grove stream drains pastureland and has such low volumes of flow (∿0.5 cfs).

Nitrogen (Figures I-49 to I-54) - The results from the extended sampling for kjeldahl, ammonia and nitrate nitrogen do not indicate any particular pattern. For waters not receiving wastewater discharges, Apple Grove drainage, Blue Spring Branch, L&N Cave and Mill Hole, TKN and ammonia levels were found to remain reasonably constant while larger fluctuations in nitrate levels were found to remain reasonably constant while larger fluctuations in nitrate levels were observed at Apple Grove drainage and Blue Spring Branch. The most significant finding of this sampling appears to be the fact that no ammonia nitrogen concentrations above 0.05 mg/l were observed. This appears to indicate that, although these streams are subject to runoff, ammonia nitrogen levels were not greatly affected by rainfall, thus implying minimal organic pollution. As expected, concentrations of all forms of nitrogen were observed to be higher in the South and East Branches of Hidden River Cave than in other streams, due to wastewater discharges from Horse Cave and Cave City.

Heavy Metals (Total Chromium, Copper, Nickel and Zinc) (Figures I-55 to I-58) - Although metal concentrations at the Horse Cave wastewater treatment plant have been greatly reduced, concentrations of nickel, chromium, copper and zinc in the South Branch Hidden River Cave, as indicated by the extended sampling program, remain at levels toxic to aquatic life.

The extended sampling program results indicate that concentrations of total chromium, nickel and zinc at the treatment plant were consistently less than EPA pre-treatment standards (Table I-47). Nickel concentrations, however, were shown to fluctuate with the October 2, 1978 effluent concentration near the limit for pre-treatment standards.

The pre-treatment standards are only mentioned here for comparison and to provide some indication of metals levels necessary to operate a biological treatment plant. The fact that the plant effluent metals concentrations are found to be within these limits does not imply that this condition is satisfactory. Metals concentrations in the effluent should be sufficiently low to protect aquatic life in the receiving waters after mixing. Because little dilution is available during base flow, metals concentration in the effluent must be reduced to approximately those required in the stream to protect aquatic life.

Because of metals deposits in the treatment plant and South Branch Hidden River Cave, measured metals concentrations in the effluent and the stream may not accurately indicate improvements until these deposits are dissipated. For this reason, monitoring of the plant influent is important.

FIGURE I-49

TOTAL KJELDAHL, AMMONIA AND NITRATE NITROGEN CONCENTRATION DURING SEPT.-NOV. 1978 AT SOUTH BRANCH HIDDEN RIVER CAVE

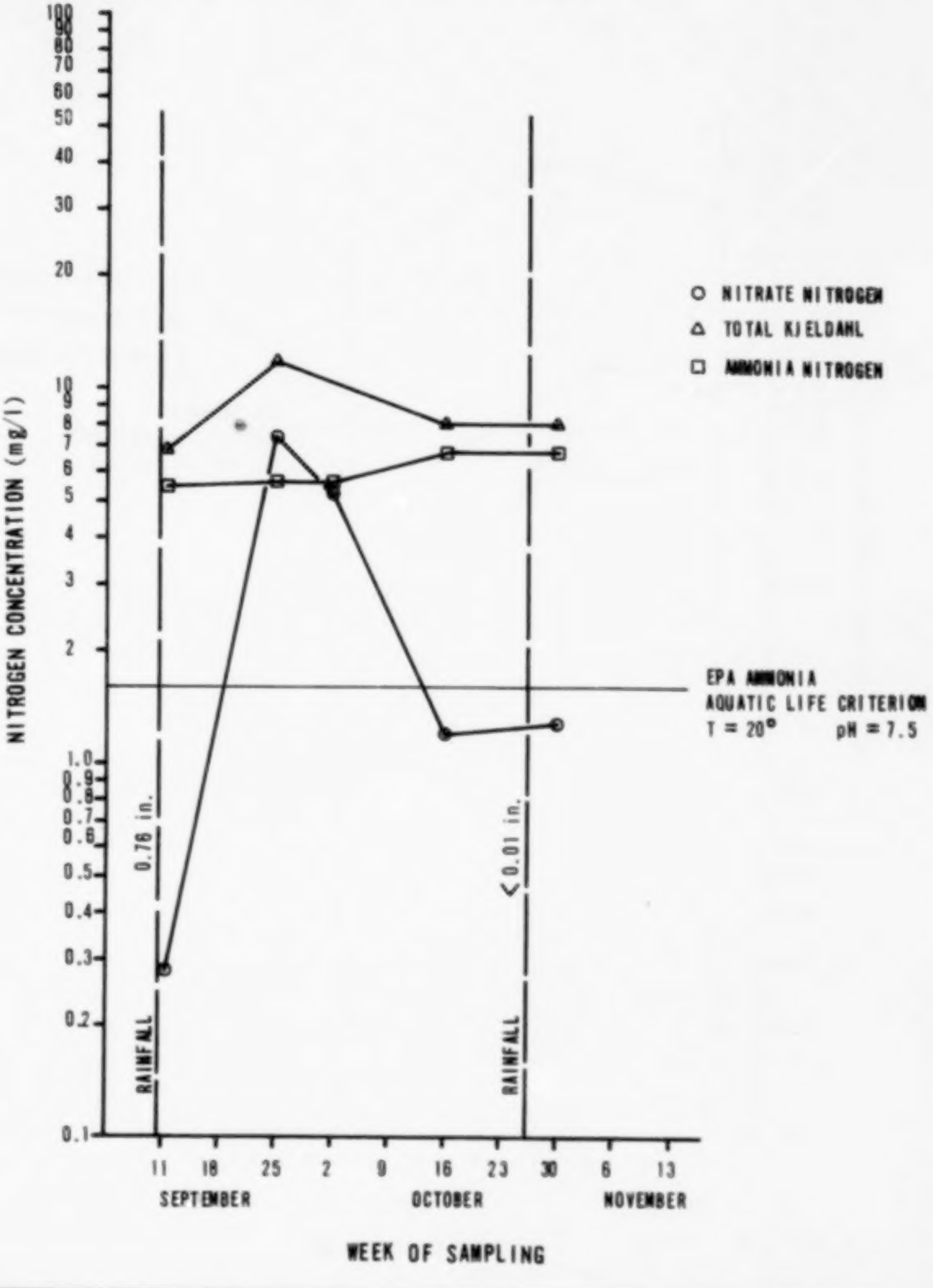


FIGURE I-50

TOTAL KJELDAHL, AMMONIA AND NITRATE NITROGEN CONCENTRATION DURING SEPT.-NOV. 1978 AT EAST BRANCH HIDDEN RIVER CAVE

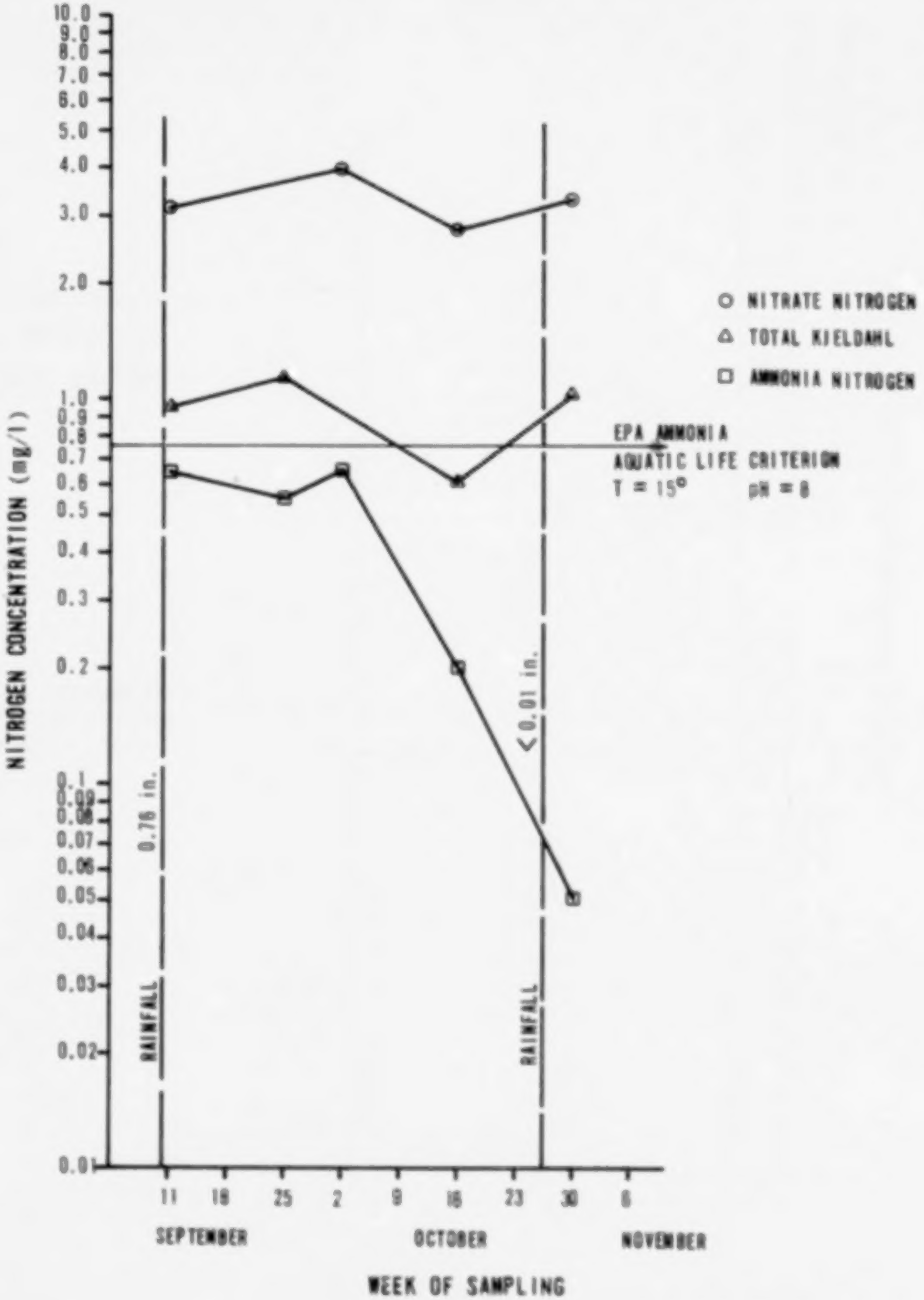


FIGURE I-51

TOTAL KJELDAHL, AMMONIA AND NITRATE NITROGEN CONCENTRATION DURING SEPT.-NOV. 1978 AT APPLE GROVE DRAINAGE

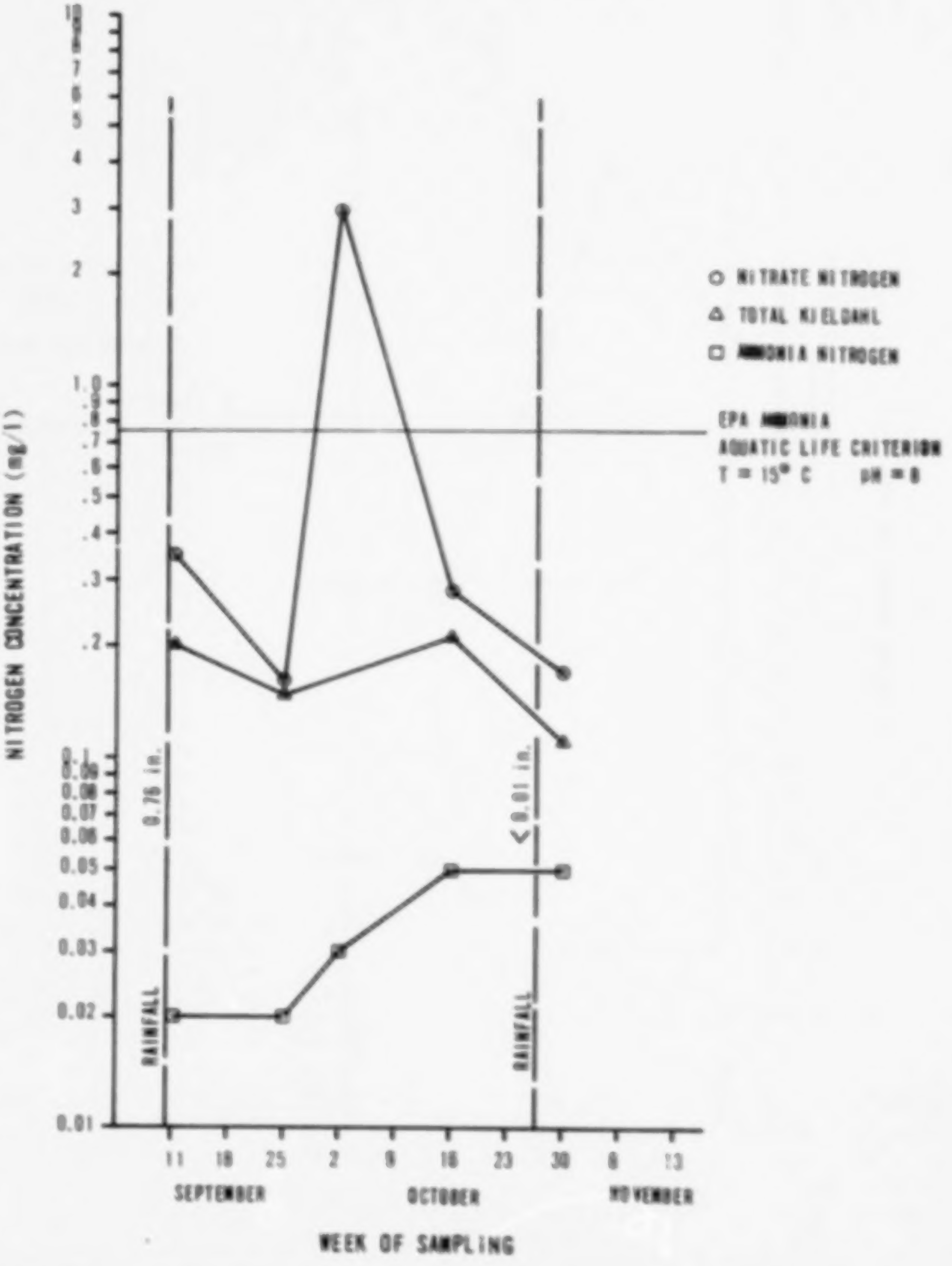


FIGURE I-52

TOTAL KJELDAHL, AMMONIA AND NITRATE NITROGEN CONCENTRATION DURING SEPT.-NOV. 1978 AT BLUE SPRING BRANCH

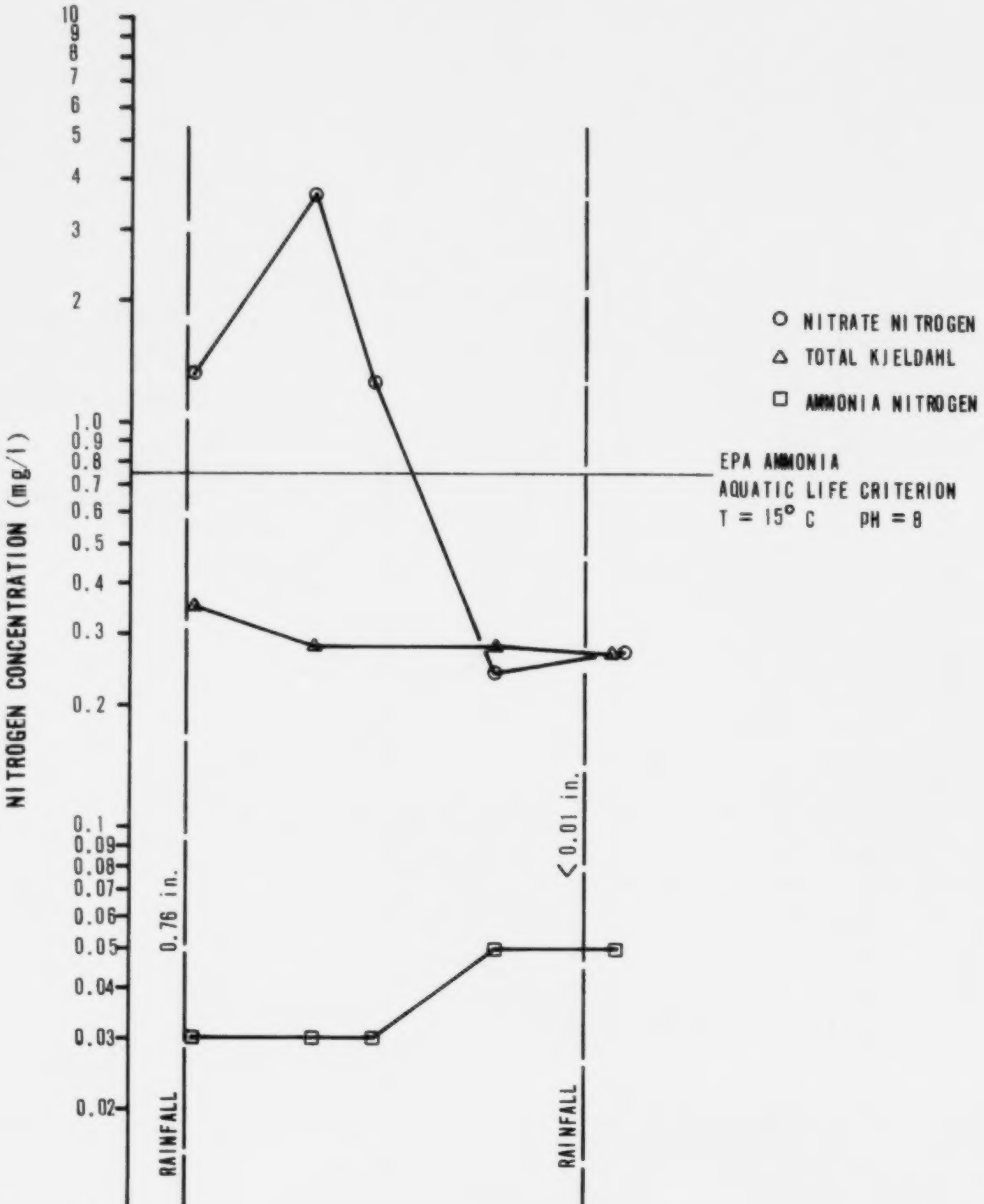


FIGURE I-53

TOTAL KJELDAHL, AMMONIA AND NITRATE NITROGEN CONCENTRATION DURING SEPT.-NOV. 1978 AT MILL HOLE

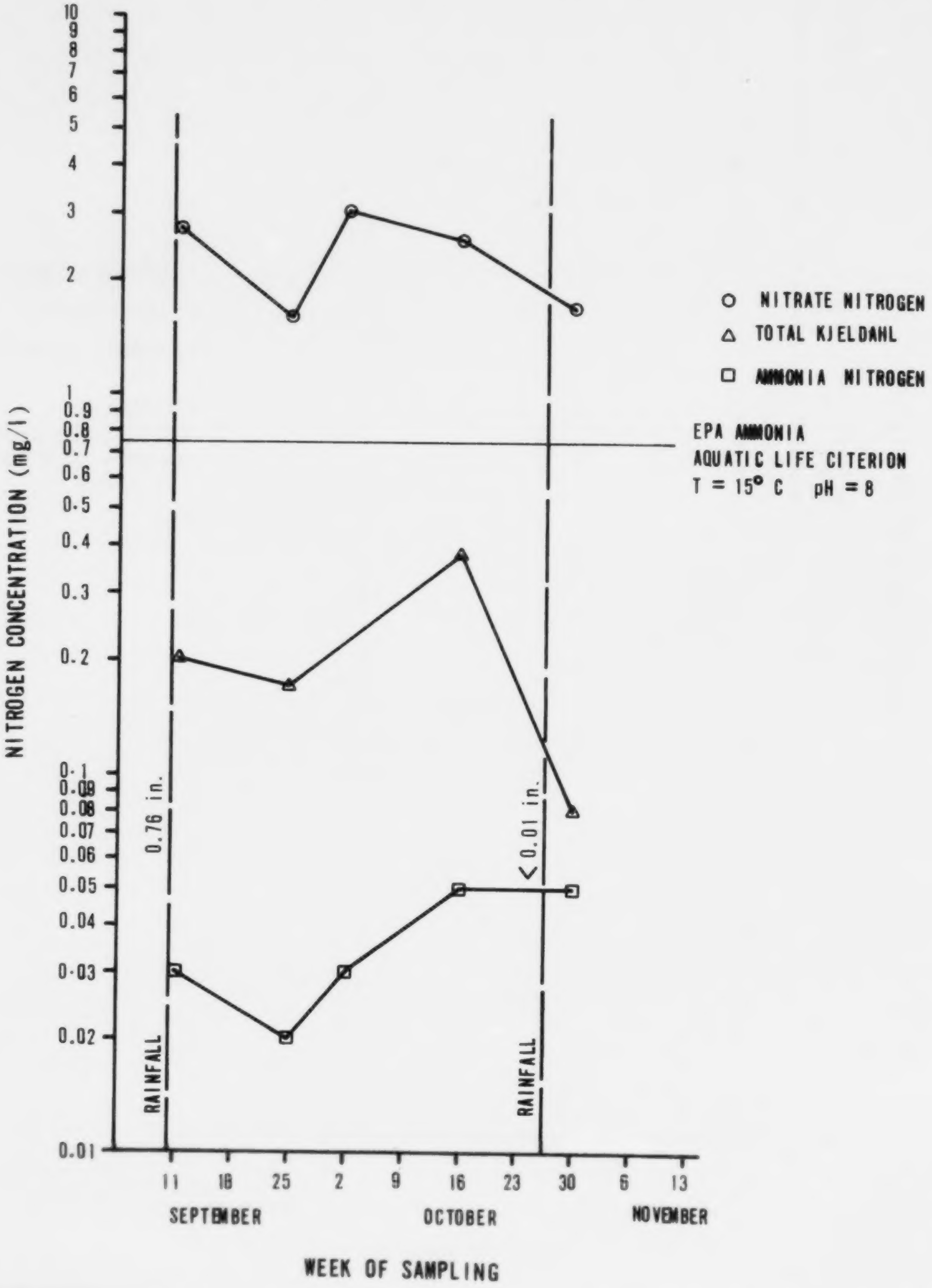
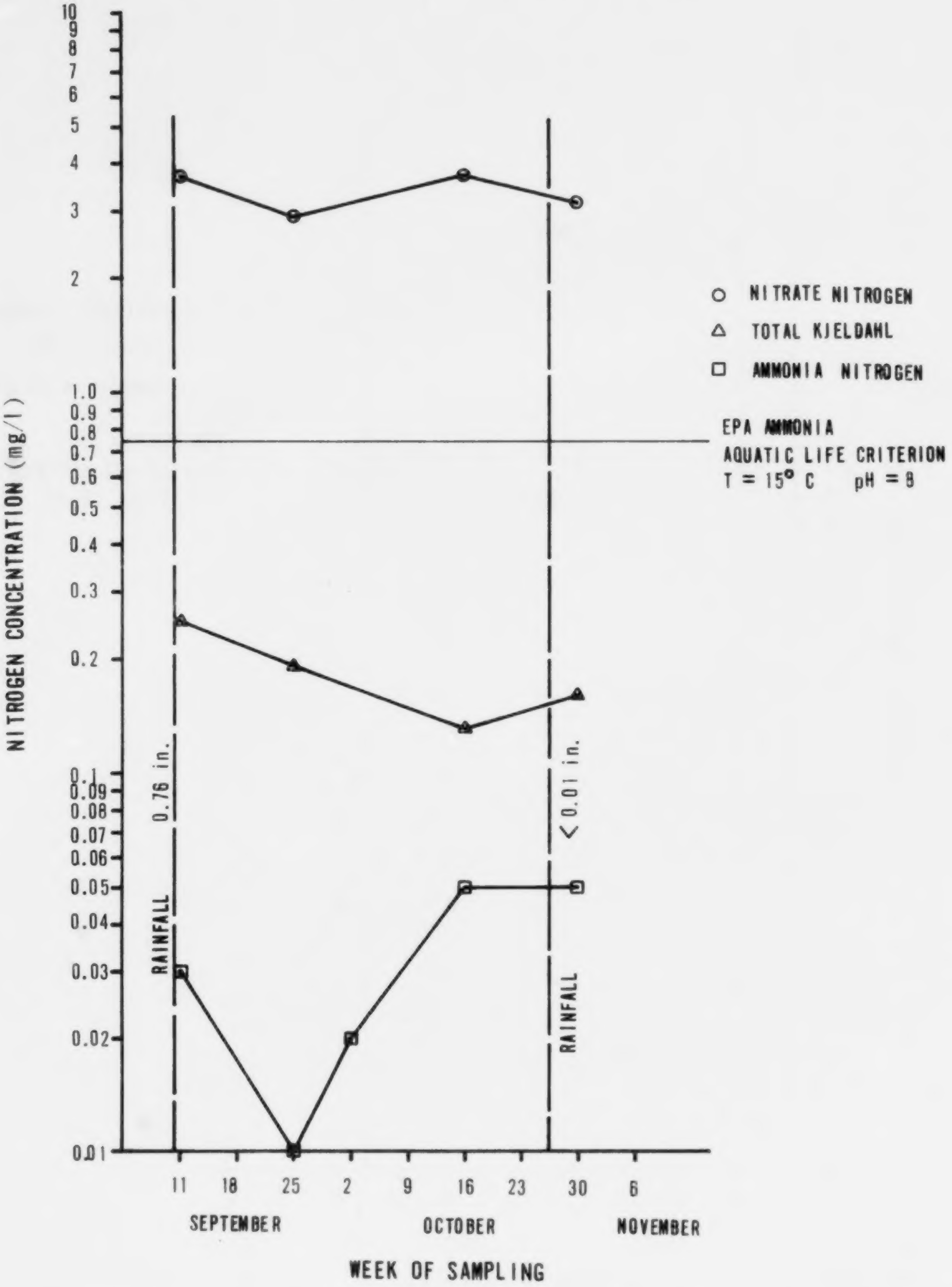


FIGURE I-54

TOTAL KJELDAHL, AMMONIA AND NITRATE NITROGEN CONCENTRATION DURING SEPT.-NOV. 1978 AT L & N CAVE



I-70e

FIGURE I-55

TOTAL CHROMIUM CONCENTRATIONS DURING SEPT.-NOV. 1978
AT HORSE CAVE TREATMENT PLANT EFFLUENT AND SOUTH BRANCH HIDDEN RIVER

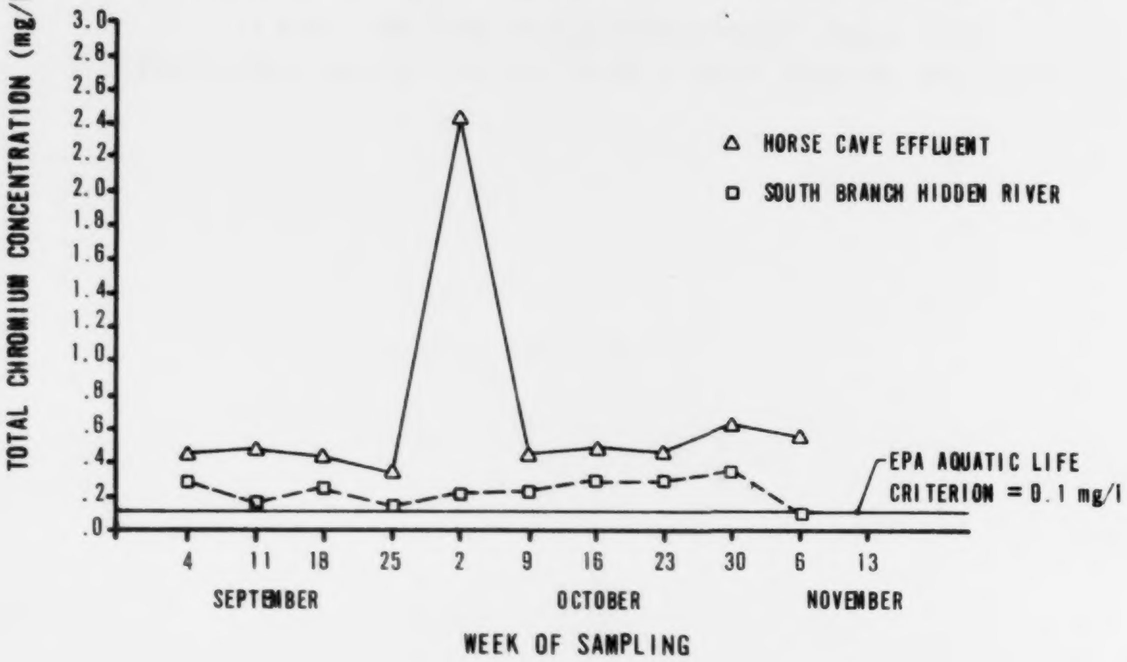


FIGURE I-56

TOTAL COPPER CONCENTRATIONS DURING SEPT.-NOV. 1978
AT HORSE CAVE TREATMENT PLANT EFFLUENT AND SOUTH BRANCH HIDDEN RIVER

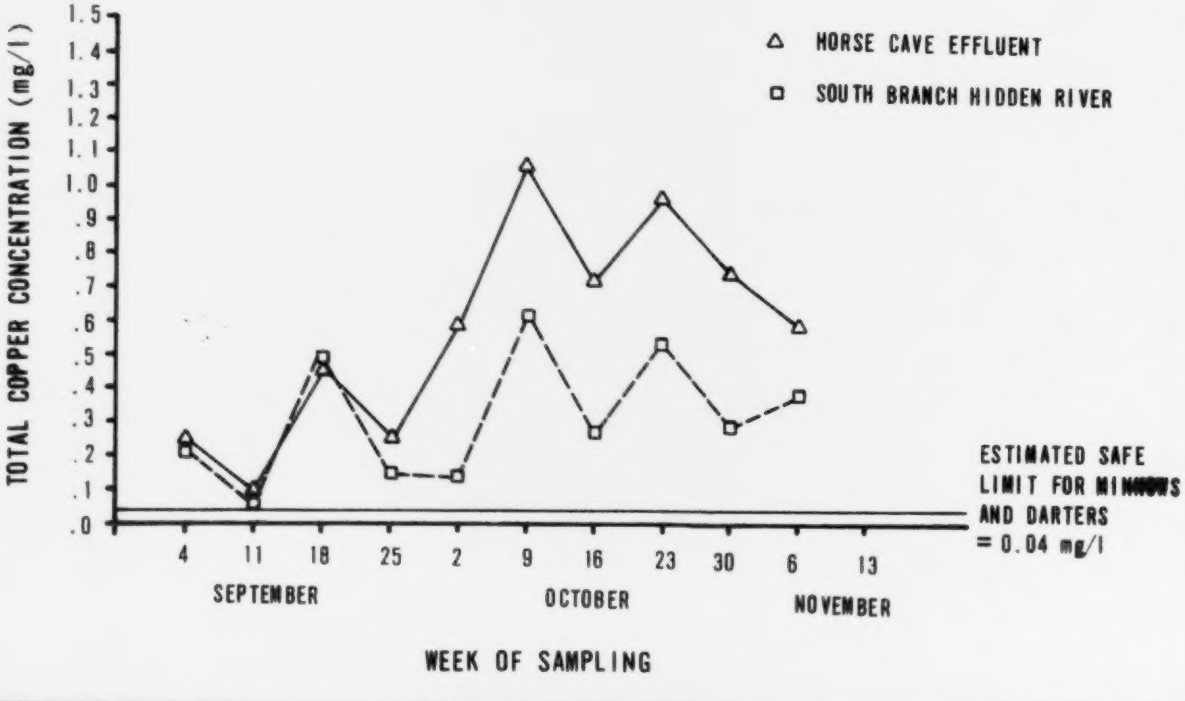


FIGURE I-57

TOTAL NICKEL CONCENTRATIONS DURING SEPT.-NOV. 1978 AT HORSE CAVE TREATMENT PLANT EFFLUENT AND SOUTH BRANCH HIDDEN RIVER

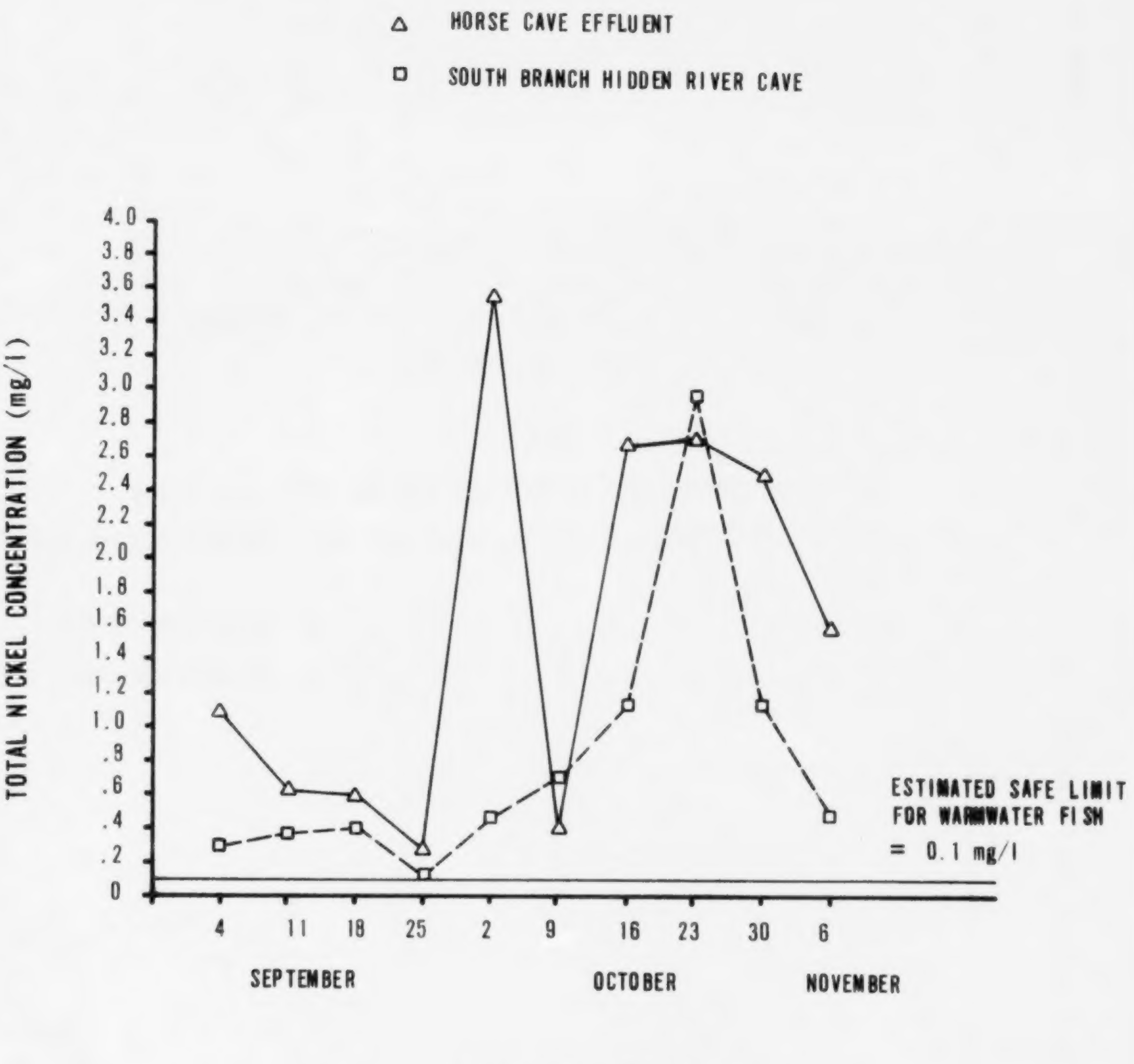


FIGURE I-58

TOTAL ZINC CONCENTRATIONS DURING SEPT.-NOV. 1978
AT HORSE CAVE TREATMENT PLANT EFFLUENT AND
SOUTH BRANCH HIDDEN RIVER CAVE

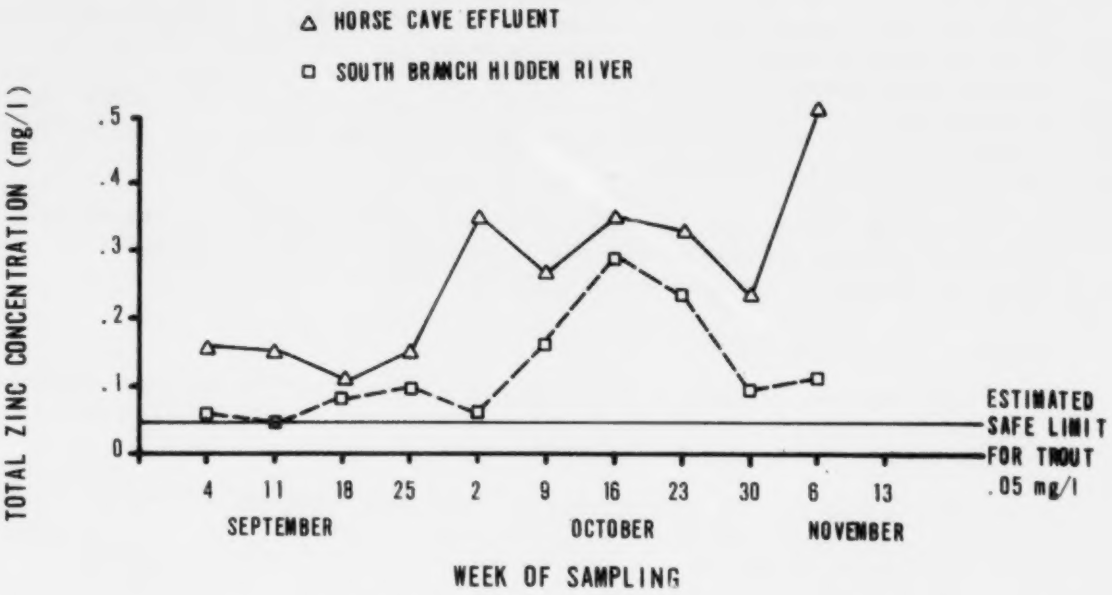
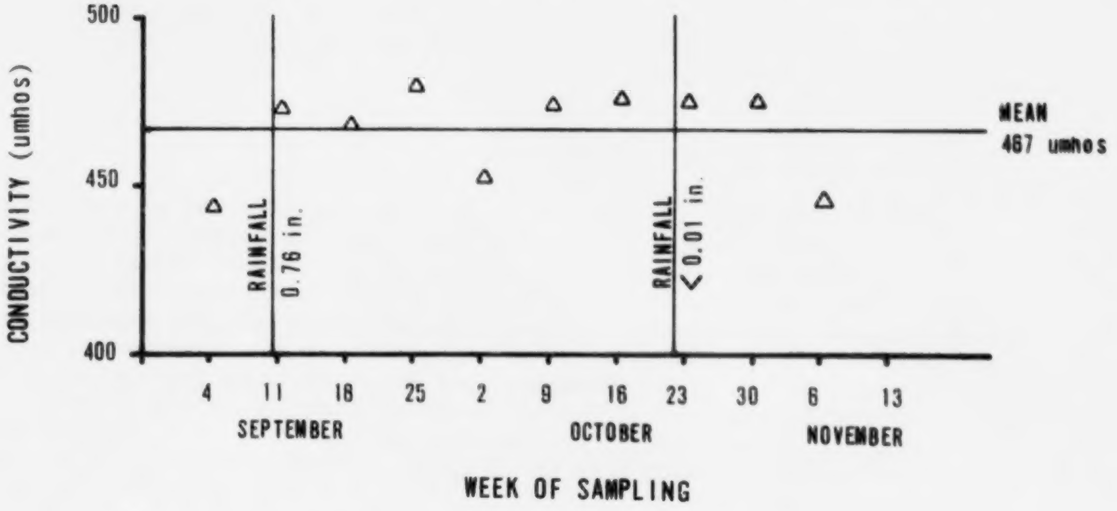


FIGURE I-59

CONDUCTIVITY LEVELS DURING SEPT.-NOV. 1978
AT L & N CAVE (#20)



Conductivity (Figures I-59 to I-64) - Conductivity measurements were made at sampling stations during the extended sampling program to monitor any significant changes in ionic constituents. Results of these analyses indicate that the ionic characteristics of the waters at Apple Grove Drainage, Blue Spring Branch and L&N Cave did not fluctuate much from week to week. Mill Hole conductivities appear to increase substantially after the September eleventh rainfall and they remain nearly constant. This may be due to continuing effects from the runoff since the Mill Hole drainage area is large. The conductivities in the South Branch of Hidden River Cave were found to be highly variable. These fluctuations, of course, are a function of the changes in Horse Cave treatment plant effluent. To some extent, East Branch Hidden River Cave conductivities were also found to fluctuate.

The most significant conclusion of the conductivity sampling is that it provides another indicator that water quality in the natural waters in the area does not appear to change drastically with time.

Limitations to the Sampling Program

Although the results of the sampling program provide an indication of water quality in the area, there are several limitations to the program that should be identified. They are as follows:

1) Except for the few parameters that were analyzed during the long-term base flow sampling program, sampling was not conducted during what is considered to be the "worst condition" the effects of rainfall runoff during base flow.

2) Except for those parameters sampled during base flow, there is no replication of data.

3) Although the results are to apply to the entire study area, not all the subsurface basins were sampled.

4) Because of limited accessibility to subsurface sites, local pollution problems may be masked by dilution at the more accessible sites. (e.g. samples at Owl Cave show no effect of any Park City waste disposal.)

5) No seasonal data are presented since samples were only collected during two flow conditions.

Although there are limitations to the sampling program, several efforts were made to mitigate their effects. The basins most subject to human pollution were heavily sampled. In addition, subsurface sampling in Parker Cave provided for monitoring the effects of runoff as waters moved through agricultural areas and did identify some local pollution problems. The extended sampling program provides some data replication. Also, dissolved oxygen measurements were taken after rainfall during base flow conditions to obtain some indication of the effects of rainfall runoff. Finally, the fact that the conclusions of the extended sampling do not differ from those of the one-time grab sampling program tends to support the findings of the program, however limited.

FIGURE I-60

CONDUCTIVITY LEVELS DURING SEPT.-NOV. 1978
AT BLUE SPRING BRANCH (#19)

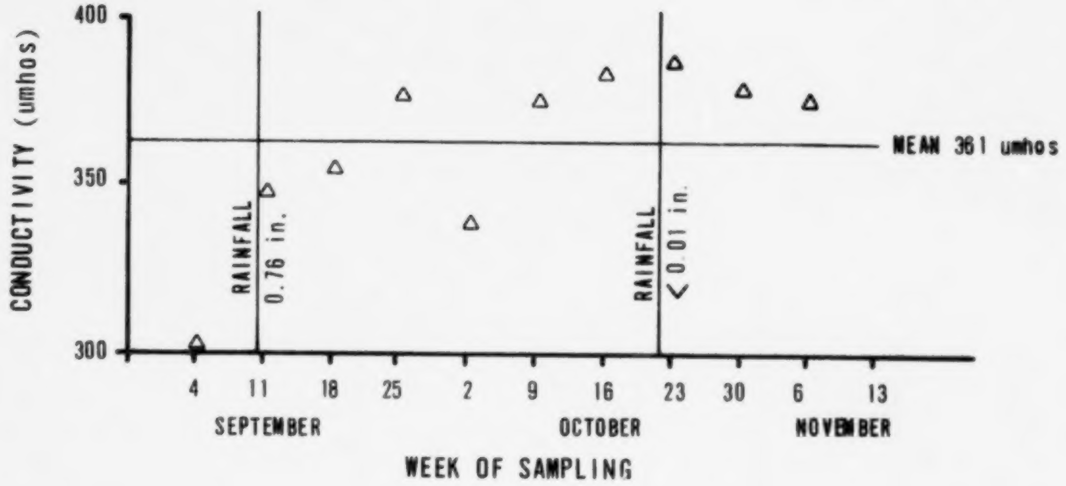


FIGURE I-61

CONDUCTIVITY LEVELS DURING SEPT.-NOV. 1978
AT APPLE GROVE DRAINAGE (#4)

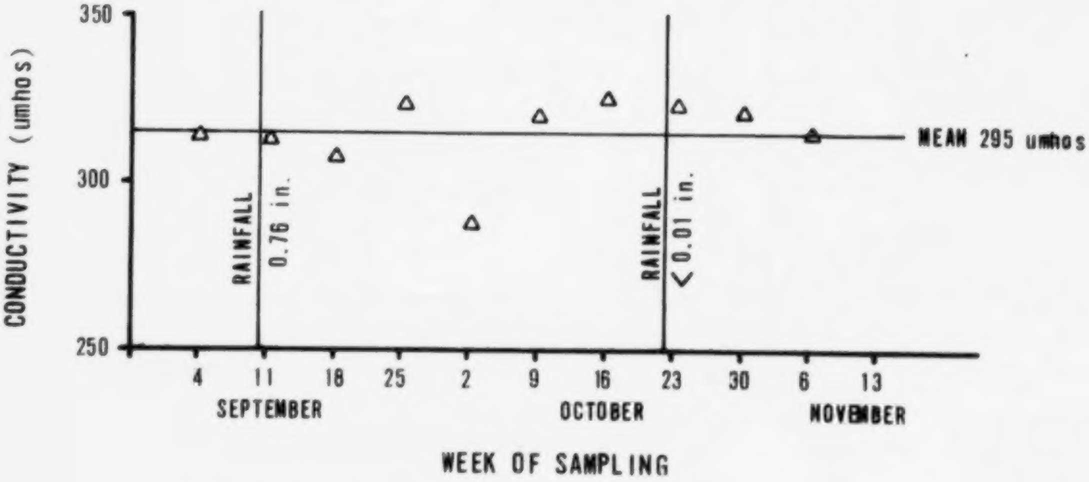


FIGURE I-62

CONDUCTIVITY LEVELS DURING SEPT.-NOV. 1978
AT SOUTH BRANCH HIDDEN RIVER (#17)

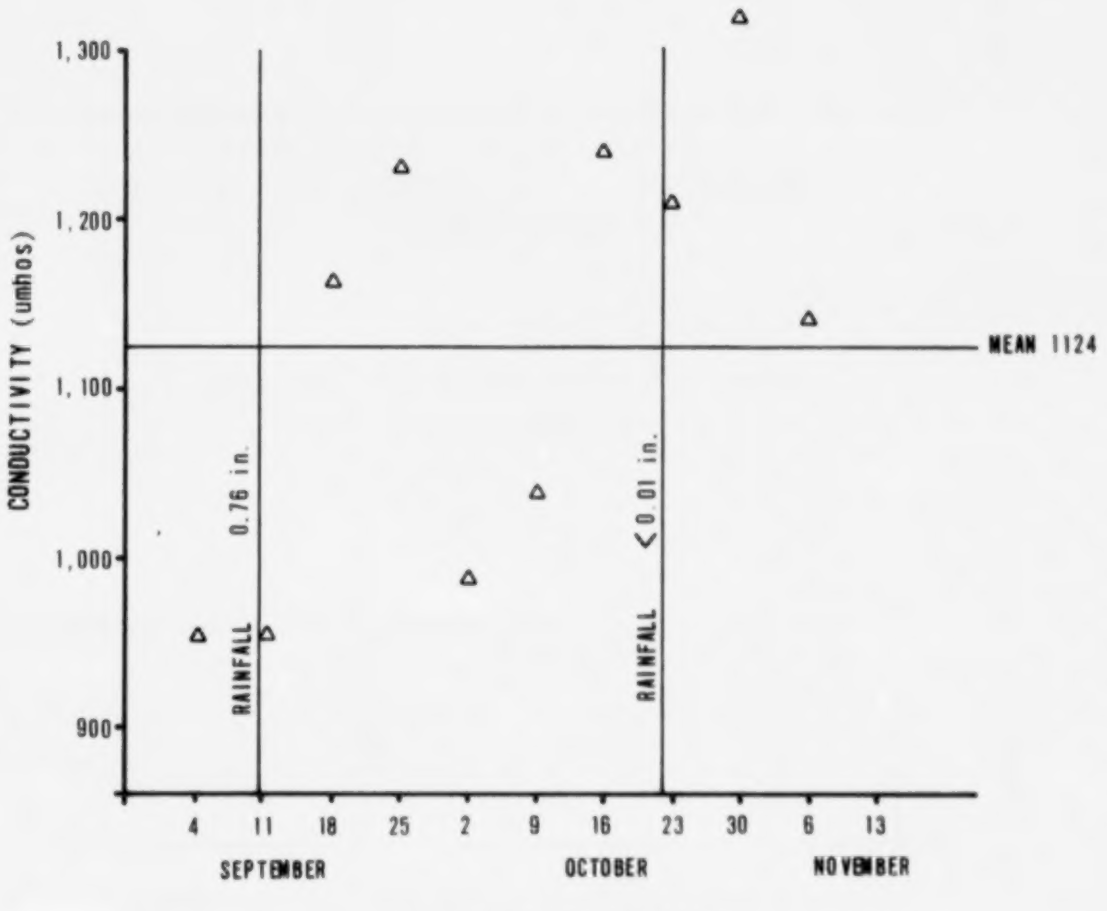


FIGURE I-63

CONDUCTIVITY LEVELS DURING SEPT.-NOV. 1978
AT EAST BRANCH HIDDEN RIVER(#18)

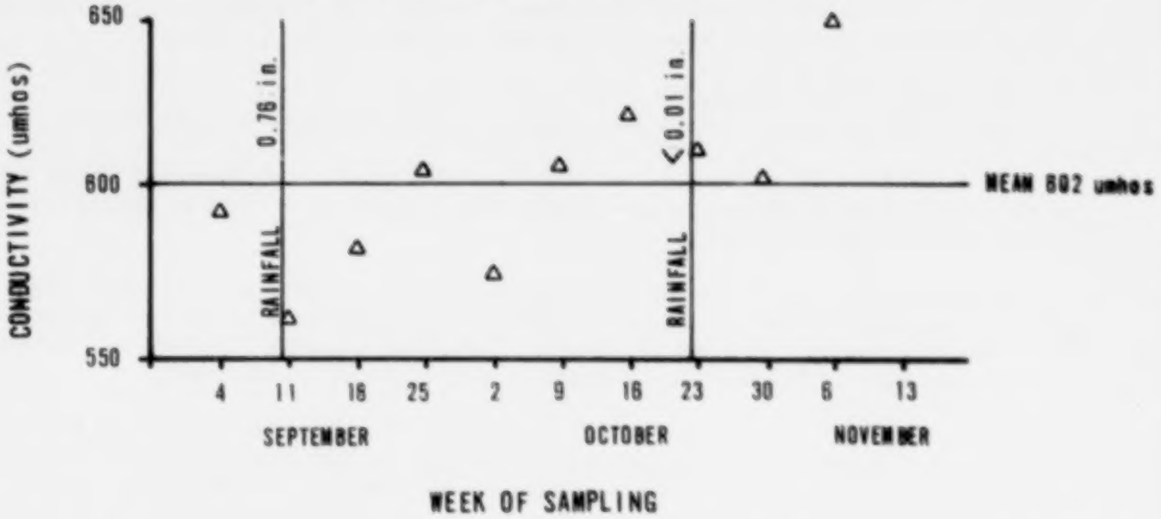
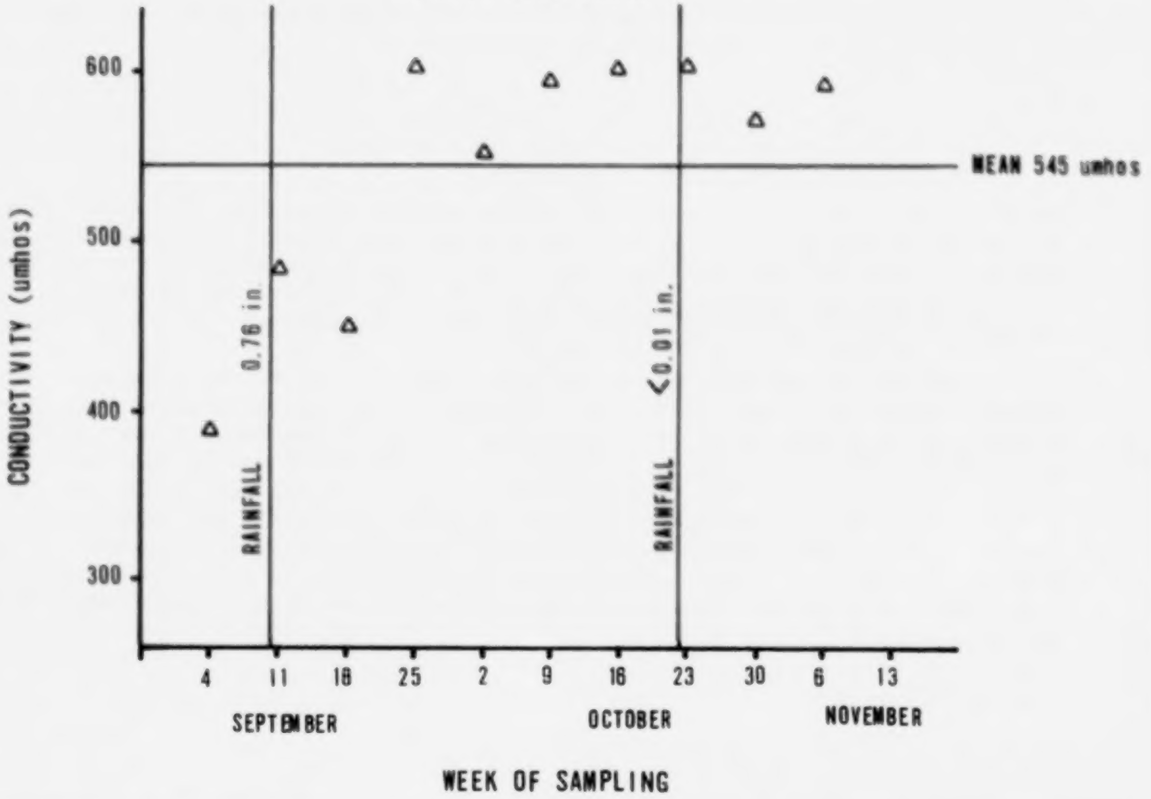


FIGURE I-64
CONDUCTIVITY LEVELS DURING SEPT.-NOV. 1978
AT MILL HOLE (#14)



Conclusions

The findings of both the one-time grab sampling program and the extended base flow sampling program are consistent. The general conclusion of the sampling program is that based on the data, the water quality in the study area appears to be generally good to excellent, acceptable for maintaining aquatic life. However, there are known exceptions including the following:

1) Most of the waters of Hidden River Cave
2) Areas of local chloride pollution in the Turnhole Spring Basin

In addition, there are undoubtedly several areas of undetected local subsurface pollution problems in the study area, though they do not significantly affect overall water quality.

Because natural waters in the area appear to be generally of such high quality, application of the aquatic life criteria appears to be reasonable in most cases. However, a general classification of aquatic life for all waters in the area may be inappropriate depending upon local conditions.

To this point only aquatic life criteria for individual heavy metals are considered. However, because several heavy metals are present in the water at one time, it is necessary to also consider the effects of mixtures of heavy metals. An organism's ability to survive in one toxicant may not be a good indication that these levels are satisfactory when other toxicants are present. According to Dr. J. L. Weber (personal communication) and Anderson and Weber (1975), copper and nickel are concentration additive, and in combination with zinc, the effects are sometimes super-additive. When two or more toxic materials have additive effects, a reduction in the permissible concentrations may be necessary. An acceptable means of assuring that the combined amounts of several substances do not exceed a permissible concentration for the mixture is through the use of the following relationship:

$$\frac{C_a}{L_a} + \frac{C_b}{L_b} \ldots + \frac{C_n}{L_n} \leq 1$$

Where C_a, $C_b \ldots C_n$ are the measured concentrations of each of the toxic materials in the water and L_a, $L_b, \ldots L_n$ are their respective permissible concentration limits derived for the materials on an individual basis (FWPCA, 1968). Should the sum of the several fractions exceed one, then a local restriction on the oncentration of one or more of the substances is necessary.

Total metals concentrations are calculated using the above formula for copper, nickel and zinc. Levels of chromium, total and hexavalent, are considered to be so low as to be negligible outside of the South Branch Hidden River Cave. Therefore, these metals are not considered in the analysis of heavy metal mixtures. Non-conservative calculations are made using the limits for warmwater fishes (minnows, darters) because limits for the cave species are unknown. The limits used are as follows: nickel - .1 mg/l, copper - .05 mg/l and zinc - .15 mg/l. More conservative calculations are prepared by using the zinc limit of 0.05 mg/l for more sensitive coldwater fish. These calculations are presented in Appendix I.

During moderate flow conditions, the non-conservative calculations indicate that total heavy metals may be excessive at stations 9, 17, and 20. Using the more conservative calculations, excessive metals concentrations are present in almost all of the sampling stations except stations 14 and 16, Mill Hole and Echo River respectively. These results are due primarily to the high zinc concentrations found during moderate flow conditions. As discussed previously, this appears to be a naturally occurring phenomenon, and because aquatic life was observed at all the sites except South Branch Hidden River Cave, these levels appear to be satisfactory for maintaining the local aquatic species.

During low flow conditions, the non-conservative calculations indicate excessive heavy metal concentrations at stations 11 and 12, sites of known oil well contamination, and site 17, South Branch Hidden River Cave. Calculations from the data at the other sites indicate that heavy metals concentrations are not too high to support warmwater species. However, conservative calculations indicate that there may be a slightly high metals concentration in Brown River and Gorin Mill. In both cases, the calculation is 1.1, just slightly above the limit of 1. Organisms may not be affected in areas where heavy metals occur naturally because the heavy metals may be in a non-biologically active state. Weber (personal communication) mentioned that metals in a mixture are capable of combining with other elements or each other, effectively rendering themselves biologically inactive. Based on observations made during field sampling, heavy metals in the groundwater basins outside of the Hidden River Cave complex do not appear to limit or adversely affect aquatic life. It will be necessary, however, to set stringent limits on the heavy metals discharged from Ken-Dec. Levels may have to be less than the acceptable limit established by EPA for each metal separately. For example, the present safe limit for nickel is 0.1 mg/l and for Cu, 0.05 mg/l for warmwater fish. Considering additive effects, however, concentrations of these toxic elements in wastewater discharges may be required to be limited to levels that will assure that concentrations in the receiving stream do not exceed 0.05 mg/l nickel and 0.25 mg/l copper.

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10. AQUATIC ECOLOGY

Aquatic ecosystems in the Mammoth Cave Area EIS Study can be categorized as surface and subsurface. Subsurface aquatic systems predominate and are discussed in the Cave Ecology section. The surface water of the Mammoth Cave area is both lotic and lentic. Lotic or flowing water systems include sinking streams, springs, karst windows, and surface streams. The major surface stream within the study area is the Green River. Lentic or standing water systems include ponds, lakes and upland swamps.

The hydrologic arrangement for the Central Kentucky Karst is schematically presented in the Surface-Subsurface Water Resources section. The major role of subsurface drainage is outlined with surface water being drained through infiltration, sinking streams, sinkholes, vertical shafts and fracture and pore systems. Surface flow in the sinkhole plain is extremely limited. The subsurface water discharges at springs along the Green River in the study area proper and along the Barren and Little Barren Rivers in the outlying areas.

There are major differences between surface and subsurface aquatic systems. Many of these differences are associated with the amount of energy flow in the systems and the diversity and stability of the biotic communities. A simplified compartmentalization of a surface stream is diagramed in Figure I-65. The major energy production is external to the system (allochthonous) in the form of leaf input. The leaves are processed by several levels of biotic functional groups which in turn support the predator populations. The internal (autochthonous) photosynthetic production is minor in lotic systems. In contrast, surface lentic systems are primarily autochthonous in nature. The allochthonous nature of surface streams allow them to assimilate pollution loads. An additional energy subsidy in the form of organic pollution to the system can be in fact beneficial to the lotic system. Only when the addition overloads or interferes with the normal processes of the system does the "pollution" actually become a problem.

Hynes (1960) divides the physical and chemical effects of pollution into five categories: de-oxygenation, suspended solids, poisons, non-toxic salts, and heat. A given pollutant often causes effects of more than one type.

De-oxygenation is usually caused by bacterial breakdown of organic matter, but is sometimes caused by other reducing agents. Acute de-oxygenation has a direct effect upon invertebrate and vertebrate populations with the most visible result being fish kills.

The addition of solids to the system can cause de-oxygenation if the solids can be oxidized and can interfere with the normal operation of the system through habitat destruction. As the suspended solids settle, invertebrate populations can be smothered as can fish nesting sites. Solids can originate from waste treatment plants, urban or agricultural run off, construction activity or several other sources.

Poisons disrupt aquatic systems in two ways. Organisms may be subjected to low level continuous pollutant concentrations or to discrete high level concentrations. The effects of low level continuous exposure varies with pollutant and species and is dependent upon the rate of transport into the body and the ability of the organism to eliminate or destroy the poison. The discrete, occasional, high level pollutant has a more direct effect in that organisms die if the lethal limit is exceeded. Either mechanism may be selective or general in its effect on the system by influencing one section of the system and thereby causing an imbalance or by impacting the system as a whole.

Important poisons in the study area include heavy metals from industry and urban run off, pesticides from agricultural areas and sulfides from abandoned oil wells (i.e. Parker Cave-Sulfur River) among others.

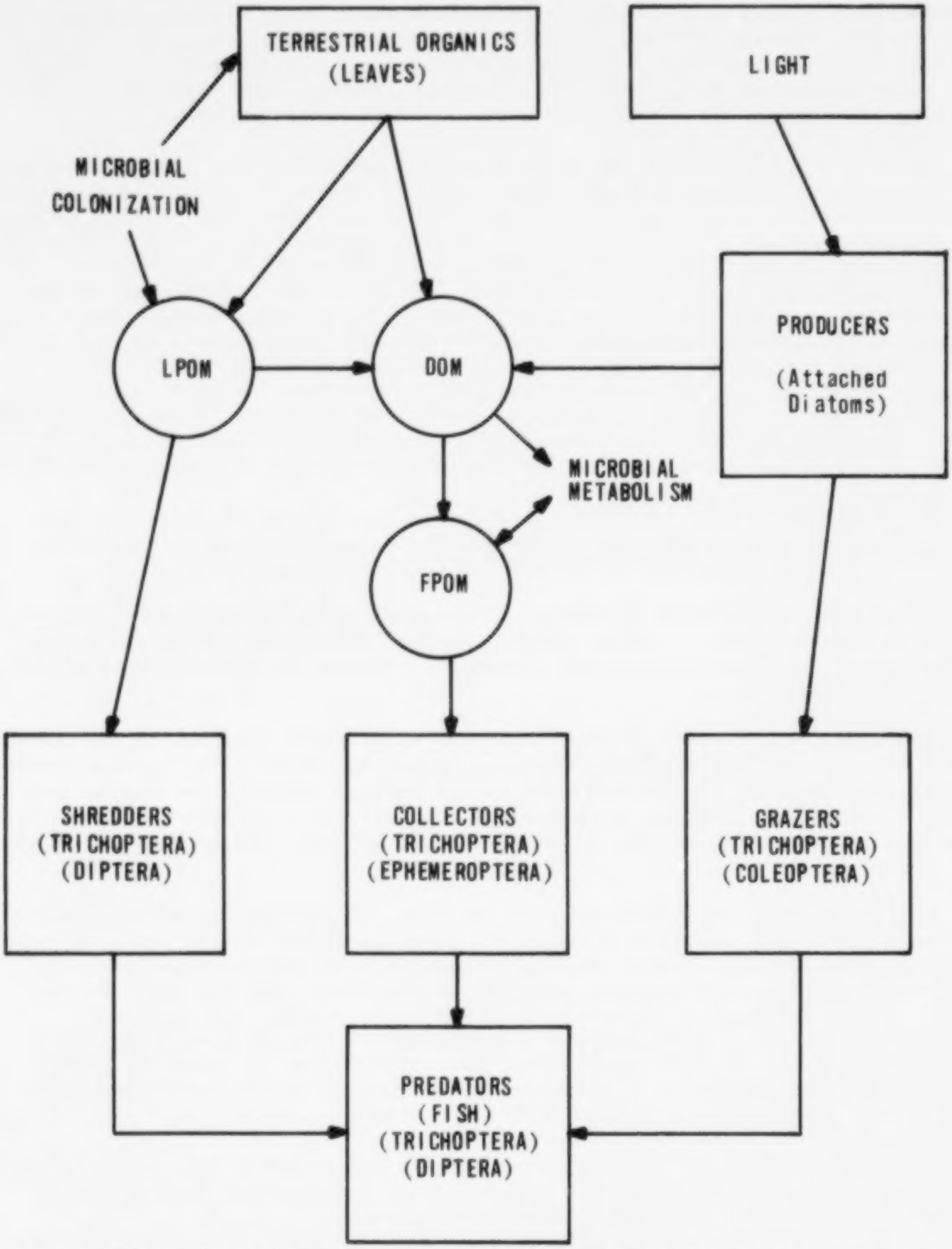
TERRESTRIAL ORGANICS (LEAVES)
LIGHT
MICROBIAL COLONIZATION
LPOM
DOM
PRODUCERS (Attached Diatoms)
MICROBIAL METABOLISM
FPOM
SHREDDERS (TRICHOPTERA) (DIPTERA)
COLLECTORS (TRICHOPTERA) (EPHEMEROPTERA)
GRAZERS (TRICHOPTERA) (COLEOPTERA)
PREDATORS (FISH) (TRICHOPTERA) (DIPTERA)

Figure I-65 A simplified compartmentalization of a woodland stream ecosystem structure. (Modified from Cummins. Et Al, 1973)

LPOM = Large particulate organic matter
DOM = Dissolved organic matter
FPOM = Fine particulate organic matter

The most important impact, from the biological view, of non-toxic salts is the stimulation of plant growth by nitrates, phosphates, and potassium. Although plant growth in streams is normally minor, the addition of these nutrient salts can cause an increase in macrophyte growth in streams and a drastic increase in algal growth in receiving lakes. Non-toxic salts primarily originate from treatment plant effluent and non-point pollution sources.

The effect of heat is both direct and indirect. Elevated temperatures can directly eliminate invertebrates and fish from areas or can indirectly impact upon populations by increasing microbial activity and decreasing oxygen concentrations. Thermal pollution of water systems is not considered to be a problem in the study area.

All these pollution categories have the same effects as natural inputs to the surface aquatic systems. Problems are only encountered when the pollution exceeds the assimilative capacity of the system. This assimilative capacity is not only a function of the pollutant but is influenced by the size, velocity, reaeration, temperature and upstream pollution loads of the surface system.

Ichthyofauna

A healthy fish community conveys an intuitive assessment of water as clean and along with the protection of drinking water supplies is a major goal of water pollution control to the local resident. Pollution affects fish populations directly and indirectly. The direct poisoning of fish produces the highly visible "fish kill". A fish kill is usually caused by the presence of toxic material or by severe oxygen depletion. Low oxygen levels are often produced by large organic loads. Indirect effects are those which, while not killing the fishes, render the area uninhabitable to them.

1. Reduction or elimination of invertebrate food supply
2. Habitat reduction by channelization or sedimentation.
3. Destruction of breeding areas.
4. Hydrologic modification of flow conditions.

Fish kills in the Commonwealth of Kentucky are surveyed by the Environmental Investigation Project and the Midwestern Fishery District Investigation of the Department of Fish and Wildlife Resources Fisheries Division. Recent annual performance reports for these two projects were reviewed for citations of fish kills within the study area (Bell, 1975; Bell, 1976; Bell, 1977; Laflin, 1975; Laflin, 1976; Laflin, 1977). No fish kills were reported in the study area proper. One fish kill was reported for August of 1975 in the Beaver Creek Embayment Barren River Lake in Barren County. Municipal sewage was the cause with an unknown number of fish being killed (Bell, 1976).

The performance reports summarize the annual activities of the Fisheries Division. The reports indicate no current sampling or stocking of fish populations in the Mammoth Cave area study. Two additional sources were reviewed in order to assess the current status of the ichthyofauna. The Department of Fish and Wildlife Resources publishes a taxonomic key to the fishes of Kentucky which includes summaries of species distribution (Clay, 1975). This key was reviewed and a list was compiled of fishes expected to occur in the study area (Appendix I). Additional information was obtained from a Fisheries Division study of the effects of oil field brines (Charles, 1964). The four-year study (1960-1963) included two sample sites within the study area and six sites outside the area but still on the Green River. The confirmed presence of these species is indicated on the list of expected species (Appendix I). While the brine pollution from the oilfield is no longer a problem within the study area, the baseline data is believed to still be adequate. Water quality in the Green River is normally high and the fish community does not appear to be impacted by the current pollution loads. The Green River is currently impounded from lock #6, below MCNP up through most of the park. The U.S. Army Corps of Engineers is currently considering the removal of lock #6. This would return the Green River to a free flowing condition and could possibly allow the introduction of new species of fish now restricted by lock #6.

Invertebrate Fauna

Invertebrate populations are not as visible as fish populations nor are they usually a subject of concern to the public. Some species are, in fact, considered nuisance populations. Invertebrates, however, are key elements in the dynamics of aquatic ecosystems. As can be seen in Figure I-65, invertebrates exist at all trophic levels and perform the bulk of the processing. They are also the food source for fish populations. Therefore, although an invertebrate kill is not as visible as a fish kill, the effect can be the same: the removal of the fish populations.

Approximately 95 percent of all described species are invertebrates. Pollution effects vary greatly over such a massive conglomeration of organisms. Two excellent reviews of pollution effects have been published (Hart and Fuller, 1974; Hynes, 1960) and should be consulted for specific effects.

Aquatic invertebrates of the surface streams have in general been poorly studied in the study area. The Fisheries Division brine study (Charles, 1964) sampled benthic macroinvertebrates in the Green River. The data is not detailed enough, however, to establish baseline information for the area.

The one group of animals which has been extensively studied in the area are the mussels (Appendix I). Two major studies of the mussel fauna within the study area have been completed. Williams (1969) conducted an investigation of the mussel fishery of the Tennessee, Ohio and Green Rivers for the Kentucky Department of Fish and Wildlife Resources. Sampling was conducted from July through October of 1968. Results were presented for three areas. Area #1 originates at the Green-Taylor countyline and terminates at the last downstream riffle which is just inside the east boundary of Mammoth Cave National Park. Area #2 runs from this riffle to Dam 4 at Woodbury, Kentucky. Area #3 is from Dam 4 to the mouth of the river. Results are summarized according to presence or absence within a given area. A second study of the Green River mussel fauna was conducted by Patch (1976). Her study area closely approximates that of the Mammoth Cave Area originating at Munfordville and terminating at Turnhole Bend. While the mussel fauna was not specifically sampled in the present study, collections were made of shells found during the invertebrate investigation. Since this sampling was not intensive and since specimens were not alive, no conclusions are drawn about changes in the mussel fauna from the previous studies.

The purpose of biological sampling in the Mammoth Cave Area EIS is two-fold: the collection of baseline information and the assessment of present conditions by the use of pollution indicating organisms. The gathering of baseline biological information makes possible future comparisons of water quality and its effects on the biological community as well as allowing for comparisons of the present community with those reported in the past. Organisms have been used as indicators of water quality since the introduction of the Saprobic System of Kilkwitz and Marsson in 1908. The presence or absence, density, and production of an organism as well as the community structure are indicative of not only present but past water quality and conditions. The advantages of biological studies over chemical studies is directly related to this time effect. Chemical studies of the water are present at one point in a stream at one given time. Water quality conditions in the stream may have been extremely different at any time before the sample (example: a plug of industrial discharge moving downstream). The biological community is subject to the continuous effects of the aquatic environment. The constant exposure of the biologic community to a changing chemical environment and the associated community changes therefore give a long term idea of water quality conditions.

The predominance of subsurface drainage in the study area has a tremendous influence on the aquatic community. The ephemeral nature of many of the surface streams in the area has an obvious impact on stream vertebrates. An overview of surface drainage was accomplished through a review of secondary sources and attendance at the 5th Friends of the Karst conference sponsored at Mammoth Cave in April by the Uplands Research Laboratory of the National Park Service. This conference included a field tour of the Turnhold Spring Basin and of selected areas of the Central Kentucky Karst. Many of the areas and sites included on this two day tour are private lands and would not have been accessible except under tour conditions. Due to the group nature of the tour, extensive sampling was not possible. The general impression of the aquatic invertebrate community in the sinking streams and springs of the area is that the communities generally have a low diversity, a low density but often contain pollution intolerant species.

As a result of this initial investigation and in order to maximize the overlap between biological and chemical sampling, the major emphasis of the aquatic invertebrate investigation was focused on the Green River and major surface streams.

In general, sampling and analysis techniques followed those outlined in Biological Field & Laboratory Methods for Measuring the Quality of Surface Waters & Effluents (Webes, 1973) (i.e., EPA Biological Methods). Quantitative sampling was conducted by means of a Surber square-foot sampler. The Surber samples were restricted to use in riffle areas in order to eliminate course habitat comparisons. Qualitative samples were collected by means of a hand net. In contrast to the Surber sampling the hand netting was conducted across the stream habitat factor in order to collect as complete a species list as possible.

One Surber sample consists of three pooled net sitings. The pooling of three subsamples generally reduces the variation between samples and increases the number of individuals in a sample. Three such pooled samples (9 sitings) were taken at each site.

Samples were not filtered in the field but were transferred directly to bottles and preserved in 90% ethyl alcohol. All samples were sorted under a compound dissecting microscope and keyed to the lowest practical taxon.

Six sample sites were selected. Three of these sites are on the Green River. The Green River site above Munfordville (GR-M-above) was chosen to provide baseline information at a site above the Munfordville waste treatment facility. The Green River site below Munfordville (GR-M-below) was chosen in order to assess the impact of the Munfordville waste treatment facility. A third site was chosen immediately downstream from Hick Spring. Effluent from the Blue Spring Creek was sampled near Hiseville, Kentucky in conjunction with the water quality study. The drainage area of Blue Spring Creek consists of crop land and pasture land. Sampling was conducted near Apple Grove, Kentucky in conjunction with the water quality study. The Apple Grove site in the Green River drainage basin with its headwaters in a bog area. The unnamed tributary runs through a cow pasture and shortly sinks to join Parker River in Parker Cave. Water flows through the Parker cave system and from there to Mill Hole; the final sampling site. The perennial stream in Mill Hole collects water from a large area and flood flow is several tens of cfs. The sink can flood to a depth of more than 60 feet. Sites were sampled in October at low flow conditions. Chemical and physical parameters for the sites are summarized in Table I-14.

The data generated by the sampling and processing was evaluated by several means. Data sheets (Appendix I) are presented which summarize the evaluations. Data sheets include the taxa found, the pollution tolerance of the taxa, the number of individuals in each taxa, the density ($\#/m^2$) of each taxa, the number of taxa in the sample, the number of individuals in the sample and the total density. In addition, the Shannon-Weaver function is used to calculate the mean diversity ($\bar{d}$)and the equitability (e) is calculated as recommended in EPA Biological Methods. Diversity is affected both by the richness of species and by the distribution of individuals among the species. The mean diversity is primarily representative of the richness of species. Low diversity indices are generally indicative of communities impacted by pollution while high indices are

TABLE I-14 SUMMARY OF FIELD DATA ON SAMPLE SITES

SITE		DATE	SAMPLE TYPE	# OF SAMPLES POOLED	VELOCITY (ft./sec.)	DEPTH (in.)	D.O. PPM	TEMP. °C	PH	HABITAT DESCRIPTION
Green River above Munfordville	#1	4 Oct 78	Surber	3	1.5	12	8.5	14.5	7.4	Riffle area-Substrate consists of equal parts of gravel and rubble-detritus
	#2	4 Oct 78	Surber	3	1.5	12	8.5	14.5	7.4	" "
	#3	4 Oct 78	Surber	3	1.5	12	8.5	14.5	7.4	Riffle area-gravel and rubble macrophytes
	N	4 Oct 78	Net	--	--	--	8.5	14.5	7.4	1, 2, 3 and deeper channel
Green River below Munfordville	#1	4 Oct 78	Surber	3	1.4	10	8.5	14.5	7.4	Riffle area-Substrate consists of equal parts gravel and rubble-detritus
	#2	4 Oct 78	Surber	3	1.4	8	8.5	14.5	7.4	" "
	#3	4 Oct 78	Surber	3	1.4	8	8.5	14.5	7.4	Riffle area-gravel and rubble macrophytes present-detritus
	N	4 Oct 78	Net	--	--	--	8.5	14.5	7.4	1, 2, 3 and deeper channel
Green River Hicks Spring	#1	3 Oct 78	Surber	3	0.9	6	8.5	14.0	7.3	Riffle area gravel and rubble sand, detritus
	#2	3 Oct 78	Surber	3	0.9	6	8.5	14.0	7.3	" "
	#3	3 Oct 78	Surber	3	1.5	12	8.5	14.0	7.3	Riffle area-rubble only macrophytes
	N	3 Oct 78	Net	--	--	--	8.5	14.0	7.3	1, 2, 3 and deeper areas
Blue Spring Creek	#1	4 Oct 78	Surber	3	1.0	4	8.2	15.0	8.0	Poor substrate-water channels through bedrock-minor detritus component
	#2	4 Oct 78	Surber	3	1.0	5	8.2	15.0	8.0	" "
	#3	4 Oct 78	Surber	3	1.0	5	8.2	15.0	8.0	" "
	N	4 Oct 78	Net	--	1.0	--	8.2	15.0	8.0	" "

TABLE I-14

SITE		DATE	SAMPLE TYPE	# OF SAMPLES POOLED	VELOCITY (ft./sec.)	DEPTH (in.)	D.O. PPM	TEMP. °C	PH	HABITAT DESCRIPTION
Apple Grove	#1	4 Oct 78	Net	--	0.4	2	7.7	15.5	7.7	Small sinking steam-substrate of silt, sand and gravel-some moss present
	#2	4 Oct 78	Net	--	0.4	3	7.7	15.5	7.7	" "
	#3	4 Oct 78	Net	--	0.4	2	7.7	15.5	7.7	" "
Mill Hole	#1	4 Oct 78	Surber	2	0.8	8	8.5	14.0	7.5	Sand-gravel substrate with detritus
	#2	4 Oct 78	Surber	2	0.8	12	8.5	14.0	7.5	" "
	#3	4 Oct 78	Surber	2	0.8	8	8.5	14.0	7.5	" "

usually indicative of cleaner conditions. The component of diversity due to the distribution of individuals among species is evaluated by comparing the diversity of a given population with that of a theoretical population and is experssed as equitability. "e" normally ranges from 0 to 1 with the higher values indicating the higher quality environment. The interpretations of these values are summarized in the EPA Biological Methods manual:

> In unpolluted water $\bar{d}$ was generally between 3 and 4, whereas in polluted water, $\bar{d}$ was generally less than 1. However, collected data from southeastern U.S. waters by EPA biologists has shown that where degradation is at slight to moderate levels, $\bar{d}$ lacks the sensitivity to demonstrate differences. Equitability e, on the contrary, has been found to be very sensitive to even slight levels of degradation. Equitability levels below 0.5 have not been encountered in southeastern streams known to be unaffected by oxygen-demanding wastes, and in such streams, e generally ranges between .6 and 0.8. Even slight levels of degradation have been found to reduce equitability below 0.5 and generally to a range of 0.0 to 0.3.

The estimates of the community values for $\bar{d}$ and e improve with increased sample size. Samples with less than 100 individuals should be carefully evaluated.

The pollution tolerance rating of the taxa is based upon the tables in the EPA Biological Methods Manual and in Hart and Fuller (1974). Intolerant (I) organisms are those which are not found in areas of moderate organic pollution or moderate reductions in dissolved oxygen. Facultative (F) organisms have a wider tolerance range and exist in areas with moderate organic pollution and reductions in dissolved oxygen. Tolerant (T) organisms can exist in areas of gross organic pollution and low oxygen or anaerobic conditions. The system of evaluating a site by the presence of species depends heavily upon the presence of intolerant species. Since tolerant species can exist under clean or polluted conditions they do not indicate water quality conditions. Facultative organisms demonstrate water of at least moderate quality. High quality water is only demonstrated by the presence of intolerant taxa. An additional problem is the dependence of such a rating on a single organism. Aquatic invertebrates drift from one point to another and the presence of one intolerant individual should be cautiously interpreted.

Results are summarized in Table I-15. The number of individuals (N), number of species (S), diversity ($\bar{d}$) and equitability (e) for each sample are included. The mean, standard deviation and coefficient of variation for these parameters are also given for each site. All three of the Green River sites indicate healthy invertebrate communities with clean water quality conditions. The same conclusions can be made from the Blue Spring Creek samples. The Apple Grove samples contained fewer individuals and species. Mean sample size is below one hundred (36) and there is probably a large degree of error associated with the estimates for diversity and equitability. These results are indicative of the small size of the stream and of the limited habitat types available for invertebrates. The community is not impacted by the quality of the water as indicated by the presence of several pollution intolerant species (Appendix I). The Mill Hole samples contained more individuals ($\bar{X}$ = 87) but fewer species

TABLE I-15: Sample Values, Means ($\bar{X}$), Standard Deviations (s) and Coefficients of Variations (s x 100/$\bar{x}$) for the Number of Individuals (N), Number of Species (S), Diversity ($\bar{d}$) and Equitability (e) sampled for the Mammoth Cave Area, Environmental Impact Statement

Site	Sample	N	S	$\bar{d}$	e
Green River above Munfordville	1	100	19	2.08	0.29
	2	104	15	3.20	0.87
	3	118	13	2.81	0.77
	$\bar{x}$	107.3	15.67	2.697	0.643
	s	9.452	3.055	0.569	0.310
	CV	8.809	19.50	21.10	48.21
Green River below Munfordville	1	121	15	2.82	0.67
	2	142	14	3.09	0.89
	3	109	8	3.24	0.75
	$\bar{x}$	124	15.67	3.05	0.703
	s	16.70	2.082	0.213	0.035
	CV	12.37	13.29	6.984	4.979
Green River at Hick's Spring	1	288	18	3.37	0.83
	2	211	19	3.28	0.74
	3	475	23	3.49	0.70
	$\bar{x}$	191.3	20	3.38	0.751
	s	107.9	2.646	0.105	0.067
	CV	56.40	13.23	3.118	8.851

TABLE I-15 (Cont'd)

Site	Sample	N	S	$\bar{d}$	e
Blue Spring Creek	1	67	15	3.45	1.00
	2	173	16	3.14	0.81
	3	99	12	3.08	0.83
	$\bar{x}$	113	14.67	3.223	0.97
	s	54.37	1.528	0.199	0.095
	CV	48.12	10.42	6.174	9.794
Apple Grove	1	25	8	2.16	0.75
	2	53	9	2.41	0.81
	3	30	9	2.48	0.83
	$\bar{x}$	36	8.67	2.35	0.797
	s	14.93	0.577	0.168	0.042
	CV	41.47	6.655	7.149	5.270
Mill Hole	1	106	7	2.15	0.86
	2	42	4	1.39	0.75
	3	114	7	1.98	0.71
	$\bar{x}$	87.33	6	1.84	0.773
	s	39.46	1.732	0.399	0.078
	CV	45.18	28.87	21.68	10.09

than the Apple Grove samples. The major impact on the invertebrate community at this site is not necessarily water quality but is associated with other stresses. Mill Mole was the only site with a substantial accumulation of sand and mud. The shifting substrate as well as other environmental conditions associated with the periodic flooding (stream velocity, stream depth, suspended solids, etc.) have a greater impact on the community than does the low flow water quality.

An overall assessment of invertebrate results for the study area indicates that pollution impacts to the major surface streams is minimal. The major impacts appear to be to the subterranean systems as indicated by the present condition of Hidden River Cave in downtown Horse Cave.

11. CAVE ECOLOGY

Background

The Mammoth Cave Area EIS study encompasses a portion of the Central Kentucky Karst Region. This area is underlain by subterrain drainage systems including sinkholes and caves. Included in the study area is Mammoth Cave National Park (MCNP). The Mammoth Cave/Flint Ridge System is one of the most extensively studied cave systems in the world. Studies conducted on this system, other caves in MCNP and caves in the sinkhole plain are beginning to define and quantify terrestrial and aquatic cave ecosystems. The knowledge of cave ecosystem formation and function is far from complete however, and studies of specific pollutant impacts on these systems is extremely limited.

The effects of pollution on underground systems and water sources is central to the Mammoth Cave Area 201 program and the Environmental Impact study. Reasonable and correct decisions concerning waste treatment and resource management must be based upon an understanding of the workings and dynamics of the impacted systems. For this reason, general cave systems and energy flow in these systems are discussed. From this base pollution effects on the cave systems can be defined and discussed.

Cave Systems

There are major differences between surface and subsurface communities in terms of community organization and energy flow. Energy fixation for surface terrestrial communities is autochthonous in nature. Sunlight is converted directly by plants (grasslands, forests, etc.) and the plant biomass is the food base for the remainder of the system. Surface streams have a reduced autochthonous capacity. The bulk of the energy fixation takes place outside the system (allochthonous) in the form of terrestrial leaf biomass. This matter is broken down and processed at several levels within the stream community. An additional small amount of energy is input by autochthonous producers (algae and diatoms).

Subsurface aquatic and terrestrial communities are nearly complete in their dependence upon allochthonous sources. A small amount of energy is fixed by bacteria. Although the amount of energy fixation at this level is negligible, it may be critical to a few species. The specific pathways of energy flow for the subsurface systems can be summarized as from surface to subsurface (Fig. I-66). Cave streams obtain nearly all of their energy budget from surface waters.

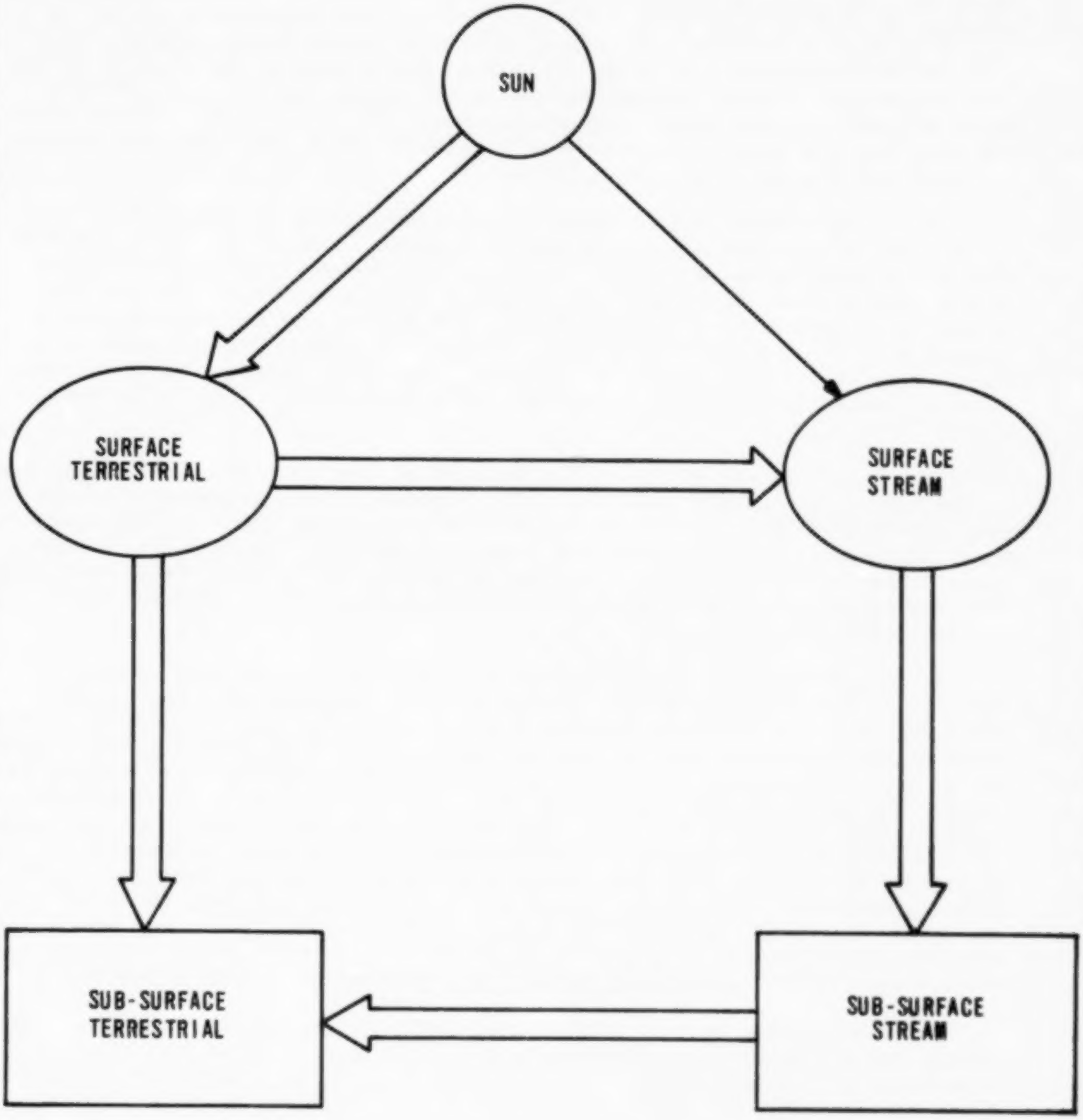
SUN
SURFACE TERRESTRIAL
SURFACE STREAM
SUB-SURFACE TERRESTRIAL
SUB-SURFACE STREAM

Figure I-66 Simplified compartmentalization of energy flow between four ecosystems.

The rate of this flow is dependent upon the surface stream itself and the manner in which surface and subsurface streams transfer materials. This transfer may be direct or diffuse. The most direct and open transfer channel occurs when a surface stream flows directly into a cave mouth. The cave stream in this case receives the entire budget of the surface stream. This energy base is not expanded along the course of the stream unless supplemental sources are present (i.e., additional streams or entrances). The more indirect and more common origin of cave streams is based upon the sinking of surface waters through gravel, silt, sand or other material. These partial blocks remove part of the organic matter from the surface streams thereby decreasing the energy content. In addition, water may seep through porous rock to form drip pools or streams. Recent studies show that the organic input from this water is small, but increases during rainfall and is significant (Barr, 1976).

The energy budget of a terrestrial cave community is derived from surface terrestrial systems and subsurface aquatic systems. Food items can be imparted directly through animal activity. This includes the nocturnal surface feeding of the cave cricket (Hadenoecus subterraneus) on epigean arthropods, the input of cricket feces to the subsurface terrestrial system, and the introduction of materials or feces by surface species. Subsurface streams deposit material by flooding and subsequent recession. The food supply for terrestrial cave communities is discontinuous in nature and patchy in distribution (Kane & Poulson, 1976).

The overall effect of the energy pathways of cave systems is relatively small energy budgets for cave communities. The response of cave communities to the low food levels have been similar for aquatic and terrestrial systems. The communities consist of few species with low density, diversity, and biomass. In addition, larger predaceous cave species typically have low turnover rates associated with low reproductive rates and long life expectancies (Barr, 1971 and 1976; Poulson, 1964).

In conjunction with the low energy budgets, cave species have adapted to a relatively constant environment. Two of the more important physical parameters are temperature and relative humidity (Table I-16). The cave entrance is in full sunlight and subject to the extremes of temperature and relative humidity common to the area. Past this point there are three traditionally recognized zones in caves. The twilight zone receives indirect sunlight and has large variations in temperature and relative humidity. The variable temperature zone does not receive detectable light but maintains variable temperature and relative humidity. The final zone is the deep cave zone and is typified by relatively constant temperature and humidity. Table I-16 subdivides the deep cave zone into three separate habitats: 1) under cap rock, 2) passage with drip and 3) stream bank. The zonation cannot be described as an ecotone since it is not a transition area between two diverse communities but is best described as an edge effect.

The distribution of food availability generally decreases as one progresses from a cave entrance to the deep cave zone. This is paralleled in the biotic parameters for the terrestrial cave systems (Table I-16). The number of species, diversity, biomass, and amount of organics in the substrate decreases with increased distance from the entrance. The slight increase in parameters for the stream bank reflects the added food component from the aquatic system. The low values for the biotic parameters are also evident in the aquatic cave environment.

TABLE I-16 TYPICAL ENVIRONMENTAL PARAMETERS FOR CAVES
(Poulson & White, 1969)

Environment	Physical parameters		Biotic parameters			
	Temperature (°C)	Relative humidity (%)	Number of Species	Diversity	Biomass (gram/hectare)	Substrate organic (% wt. loss on ignition)
TERRESTRIAL						
Entrance	10-30	10-60	100-300	1.5	1,000,000	5-20
Twilight zone	0-20	10-80	50	0.5	300	2-10
Variable T zone	3-13	30-90	10	.2	100-5,000	1-5
Under cap rock	10-13	80-95	0-3	.4	20	0.1-1.0
Passage with drip	12-13	90-100	3-7	.9	30	.2-1.0
Stream bank	7-15	95-100	5-11	1.1	20	.5-5
AQUATIC						
Sinking stream	11.15		100	2.0	2,500	5-15
Cave stream, diffuse input	10		0-3	0.5	100	.5-1
Cave stream concentrated input	10.5		2-7	1.0	325	1-2
Cave stream, underground course of surface stream	11.8		8-20	0.4	50	2-6
Vertical flow	12		0-3	.2	5	0.5-1.5
Drip pools	15.8		0-2	.2	1	.1-0.5

When compared with other cave systems, the biota of the Mammoth Cave/Flint Ridge system is extremely diverse. Barr (1967) has compiled an extensive summary of the biota and the associated literature. Cave animals are separated into three categories. "Trogloxenes" are accidental or voluntary cave animals which cannot complete their life histories within the deep cave zone. "Troglophiles" are facultative cave dwellers which can survive inside or outside of caves. "Troglobites" are obligatory cave dwellers which live and reproduce within the cave.

Trogloxenes are normally restricted to the entrance and twilight areas while Troglobites are usually restricted to the deep cave areas. Troplophiles have the widest range, can occur in all parts of a cave and often migrate outside at night to forage. Of the approximately 200 animal species collected in Mammoth Cave 22% are troglobites, 36% are troglophiles, 22% are trogloxenes, and 20% are accidentals.

Barr (1967) cites three major reasons for this relatively large diversity: cave size, amount of study, and geographical/geological location. Mammoth Cave is an exceedingly large cave system and provides a large variety of micro-environments for colonizing. The environmental factors include traditional physical and chemical parameters. In addition, current research (Poulson, personal communication) is identifying community assemblages based upon substrate type and caloric availability. The Mammoth Cave/Flint Ridge system has been the subject of extensive and prolonged biological study. This research is not limited to the Mammoth Cave/Flint Ridge system but is also conducted in other caves within the park and the park and at several caves outside the park including Parker's, Hanson's, and Walnut Hill Caves. These studies provide a data base for future comparisons of cave community types.

The cave biota of the study area has been further enhanced through its unique geographical/geological position. The relative isolation of species and communities has led to four major regional cave faunal communities in the Interior Low Plateaus. All four of these regional faunal communities exist in Kentucky and the EIS study area overlaps two: The Pennyroyal fauna and the Cumberland Saddle fauna. The south Pennyroyal (Mammoth Cave) fauna is present in the northwestern part of the study area and is generally present along the Pennyroyal Plateau from Munfordville to Bowling Green. The southeastern section of the study area is located in the Cumberland Saddle Region. Although these regional faunas are distinct some cross region dispersal has occurred. The exceptionally diverse fauna of the Mammoth Cave/Flint Ridge system is believed to have originated from local speciation and immigration via north and south Pennyroyal corridors as well as along a Cumberland saddle corridor (Barr 1967).

Karst Area Pollution

There have been several well documented ground water and cave pollution incidents within the EIS study area. Perhaps the most graphic and obvious example is the current state of Hidden River Cave in downtown Horse Cave. A chronology of events leading to the current state has been assembled from a variety of sources (Austin, 1978; Austin, personal communication; The Courier Journal, Oct. 2 and Oct. 4, 1978; Quinlan & Rowe, 1977). Hidden River Cave was used as a water supply from 1887 through 1943. The site is the type locality for the Horse Cave Blind Fish, Typhlichtys osborni (≡ subterraneous) which was discovered in 1905. From this period through the early thirty's the population appears to have been healthy.

Oil refinery waste was dumped into a sinkhole south of Hidden River Cave in 1931 and appeared in the cave. In 1938 a highway (now 31 W) was completed in the area and development along the highway increased. In the early 40's the range of the Horse Cave Blind Fish was restricted to areas upstream of a cheese plant effluent discharge point. By 1950 the entire population had died off. Subsequently, the construction of the Horse Cave Treatment Facility (1964) and the combination of heavy metal effluent (1970) and creamery waste apparently has led to the extremely degraded conditions currently present. While it is not known how far down stream the environment is significantly impacted, Quinlan and Rowe (1977) have found evidence of elevated heavy metal concentrations at springs along the Green River 4 to 5 miles away from the treatment facility.

An additional dairy product problem occurred in 1970 when an estimated 340 tons of whey were dumped into a sinkhole approximately 5 miles southeast of Smith Grove. This action resulted in the fouling of the Smith Grove water supply for more than one month at which time the water quality improved to its previous quality.

Sewage effluent spills have been reported on two occasions at the Great Onyx Civilian Conservation Center (Job Corps). The initial spill was from a single lagoon system. The effluent flowed approximately 100 yards across the surface to a fissure where it is known to have entered the cave system. A second spill of chlorinated effluent occurred through a valve in the pipeline to the Green River.

An additional threat to the cave fauna from the Job Corps is the presence of buried fuel tanks at the site. While no leakage is known from these tanks such an event did occur in Horse Cave in 1975. From February until November of that year approximately 4000 gallons of gasoline leaked from underground tanks. Gasoline fumes were detected in the basements of surrounding buildings and represented an extremely hazardous condition. A similar incident near Trenton, Georgia in 1966 left one spelunker dead from an explosion and two rescue team members dead from smoke and fumes.

A similar gas-related incident occurred near Cave City on December 1, 1978. A full 1,800 gallon tanker truck overturned, spilling an undetermined amount of gasoline. Although some of the fuel spilled into a farm pond, the majority of the spill seeped into the ground (Glasgow Daily Times; December 3, 1978).

While these are certainly spectacular examples of pollution, specific impacts on cave biota are seldom observed. The obvious reasons for the sparcity of observed effects are the inaccessability of most cave and groundwater systems and the lack of a precise chronology of events at those systems where observation is possible.

The length of stream which is affected by the pollution is extremely hard or impossible to estimate. For example, the pollution present in Hidden River Cave in downtown Horse Cave is greatly reduced by the time the stream reaches the Hidden River Complex near the Green River. In actuality, the distribution of the cave biota throughout the sinkhole plain is largely unknown simply because there are no known entrances to the subterranean systems.

While it is not always possible to gain direct access to the caves and underground drainage systems, it is possible to discern the underground drainage basins through dye trace studies. An extensive amount of dye tracing has been conducted by Quinlan et al. (1977, 1978). While work is not yet completed, it is possible in many areas to anticipate where impacts will occur from surface activities and water pollution.

Pollution Effects

There has been very little research done on the toxic effects of pollution on the cave fauna. However, an understanding of the dynamics and relationships within terrestrial and aquatic cave systems can produce a general concept of pollution effects on the cave biota. The cave system has evolved in a remarkably consistent environment. The variations in temperature and moisture have been discussed earlier and typify the environmental parameters of cave systems. An additional component is the availability of food in the cave environment. Most of the food sources are low in nutritional value (calories available per gram of food per time per area) but very consistent (low variability in availability and renewal). Cave systems are therefore typified by low payoff/low risk ratios.

The relatively constant low grade food does put severe limitations on the cave community. These conditions restrict the diversity and stability of the community. Cave systems are typically low in diversity. The limited resources often restrict cave populations to low density, particularly for the larger species. The low diversity therefore is often a function of few species and of few individuals.

There is a good deal of evidence which supports the theory that low diversity is accompanied by low stability. Stability implies a dual concept of resilience and persistence. Resilience or elasticity is the degree to which a community can recover from a disturbance. Persistence relates to the resistence of a community to a disturbance. Cave systems have low stability in terms of both persistence and resilience. The adaptations of the community to the restrictive energy budget precludes those species from utilizing a high energy input. Such an input favors species which can exploit the additional resource by rapid reproduction, and can eliminate species with slow reproductive rates but long life times (i.e. cave crayfish). The low reproductive rates also imply a low degree of resilience since species cannot rapidly reproduce to maintain population levels. Aquatic communities have particularly low resiliency since they are usually restricted in terms of area and number.

Stability, therefore, is a measure of community reaction to perturbation or disturbance. Poulson and Kane (1976) have examined the kinds of disturbances important to biological systems in caves. They have developed Action-Result-Mechanism sequences for several examples (Table I-17). While these sequences are simplified representations of actual processes, two factors should be emphasized. Many of the disturbances have multiple effects, and surface activities produce major impacts on cave systems. The interrelations of the kinds of disturbances caused by improper land use practices and the resulting simplification of the cave community are shown in Figure I-67. One effect which is not included is the introduction of new species under increased nutrient loadings. This can be a major impact if the invading species can out-compete or prey upon the existing troglobites. The major examples of ground water pollution in the study area supports the contention the surface activities can produce major impacts on the cave systems.

TABLE I-17 KINDS OF DISTURBANCE (example-result-mechanism)
(Poulson and Kane, 1976)

I. Physical-chemical stress

A. Flood(e.g. channelization)
Cold-dry air(e.g. new cave entrance)
result
decreases diversity of species especially predators
mechanism
larger predators less tolerant of stress

B. Lessen moderate stress of seasonal floods
result
decreases diversity of species
mechanism
food renewal less; may allow some species to escape predation as predators are food limited

II. Nutrient stress

A. Excess Nutrient
1. people litter
result
little change
mechanism
flash cubes,etc.inert; wood and paper like natural input and not easily monopolized by noncave species (if not in excess wood may favor specialized cave species)
2. Domestic sewage with high inorganic nutrients and toxins...see III
result
domination by spp at beginning of food chain (e.g. cave fish)
mechanism
favor fast-reproducing decomposers which may use up oxygen

B. Remove food type (seeIV) re all removed and see V A,B if remove a patch of food

III. Toxin stress

A. Heavy metals (e.g.mercury)and pesticides(e.g.DDT, PCB)
result
simplified community (dominance of small species and loss of large e.g. fish)
mechanism
toxins accumulate since ingestion egestion+excretion +detoxification of toxins along food chain to long-lived top predators (e.g.fish and crayfish)

B. Carbide
result
local loss of whole community if small or destabilization(see V B)
mechanism
temporary high pH (caustic alkaline)kills microorganisms on which other species depend

IV. Removal of one species

A. cave rat or cave cricket or bat (breeding)
result
loss of whole community or more
mechanism
foundation species that provide food for for a component community

B. Predator
result
decrease diversity of prey species
mechanism
keystone predator eats prey species that monopolizes a resource e.g.space

C. Detritivore
result
little effect except in simple system with few species
mechanisms
remove species responsible for process of succession

V. Simplify Habitat Structure

A. Remove rocks,fill up mud cracks, spread out pile of rat feces
result
more fluctuations in populations and local extinctions
mechanism
lose refuges from predators and flood or microclimate stress=fewer sources for recolonization

B. Remove patch of habitat(on a larger scale a cave)
result
more fluctuations in populations and local extinctions
mechanism
lessens"spread of risk" e.g.different patches have different susceptability to different risks and species show local adaptation to patches and caves=genetic variation=ability to adapt to changes in environment

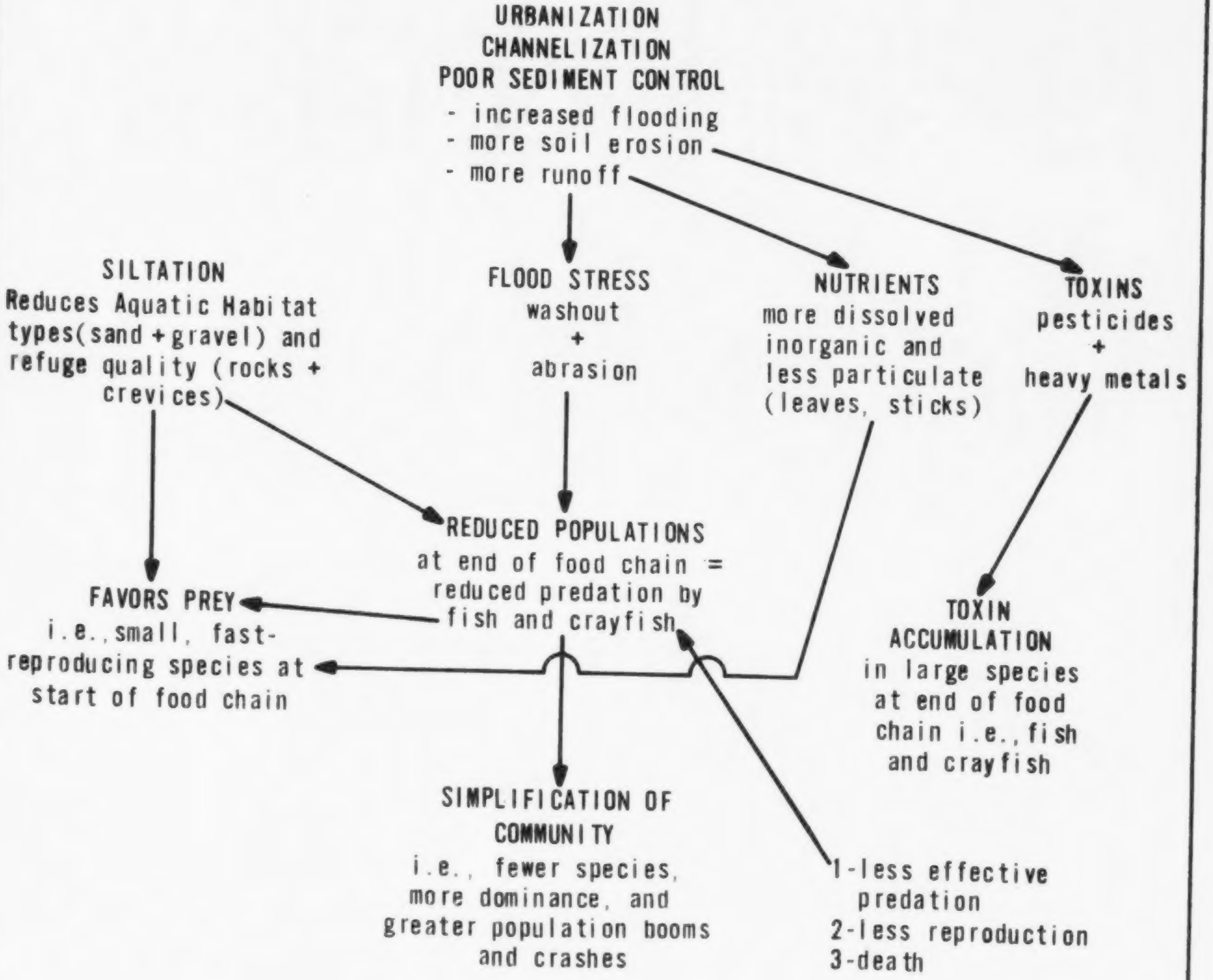
URBANIZATION
CHANNELIZATION
POOR SEDIMENT CONTROL
- increased flooding
- more soil erosion
- more runoff
SILTATION
Reduces Aquatic Habitat types(sand + gravel) and refuge quality (rocks + crevices)
FLOOD STRESS
washout + abrasion
NUTRIENTS
more dissolved inorganic and less particulate (leaves, sticks)
TOXINS
pesticides + heavy metals
REDUCED POPULATIONS
at end of food chain = reduced predation by fish and crayfish
FAVORS PREY
i.e., small, fast-reproducing species at start of food chain
TOXIN ACCUMULATION
in large species at end of food chain i.e., fish and crayfish
SIMPLIFICATION OF COMMUNITY
i.e., fewer species, more dominance, and greater population booms and crashes
1-less effective predation
2-less reproduction
3-death

Figure I-67. Interelations of Kinds of Disturbances caused by improper land use practices resulting in the simplification of the cave community (Poulson and Kane, 1976).

Stitt (1976) has assembled a list of externally derived impacts on caves (Table I-18). The data has been organized to summarize various impacts for environmental impact statements. While the table is not complete, it serves as a starting point from which the impacts from various activities can be estimated on a case by case basis. One factor that is obvious from this list is that many impacts on cave systems are irreversible, irretrievable or extremely long term. Although several of the actions listed in the table will probably not be primary impacts in this study, several of the actions will be primary or secondary impacts of any action within the study area.

Heavy Metal Studies

The discharge of heavy metal laden effluent has been a serious and chronic problem in the study area. The current state of the Horse Cave treatment facility is largely due to the toxic effects of heavy metals on the plant's biological treatment systems. The study of heavy metal concentrations along with other parameters in springs along the Green River led to conclusions concerning the independence of the conduit-flow system of springs and caves and the diffuse flow system intercepted by wells (Quinlan et.al., 1975). These studies eventually led to the discovery of the Hidden River Complex. Ken-Dec has recently begun operating a pre-treatment system which is reducing heavy metal levels in their effluent. At the time of the low water sampling run, however, chromium and nickel, while greatly reduced, were still high. The immediate effect on heavy metal concentrations at the Green River Springs is not known.

Toxicity testing on cave animals is extremely limited. Barr (1976), however, has conducted a study of the effects of nickel, chromium, cadmium and sulfide on three invertebrates. The design and results of this study are interesting for several reasons. Three relatively small, detritus feeding crustaceans were chosen for test species. An evolutionary "old" troglobite (*Asellus stygius*) was found to be more sensitive to heavy metal toxicants than a "new" troglobite (*Crangonyx packardi*) or a non-troglobite (*Lirceus fontinalis*). However, the evolution of a lower metabolic rate by *A. stygius* made it less susceptable to the respiratory poison sulfide. A 96-hour LC_{50} of 75.55 ± 3.84 ppm nickel was found for *A. stygius*. Results of the toxicity tests were not entirely indicative of the toxic effects on the species or the anticipated effects on the cave community. Continued observation of specimens of *Asellus* and *Crangonyx* after removal from test solutions indicated that the effects of exposure to nickel persisted over several days with additional mortality. No estimate was made of sub-lethal effects. In addition, the toxic effects appeared to be much greater on molting isopods. Barr states that the toxic effects on microorganisms, a good source for the crustaceans, could conceivably be a greater impact.

Barr selected his test species for two specific reasons. The three species represented an evolutionary gradient of adaptation to the cave environment. In addition all three species could be collected in sufficient numbers to conduct the tests while having minimal impact on the populations. An aspect of the heavy metal pollution problem which was not studied was the bio-concentration of toxic metals in the bodies of large, predaceous troglobites (blind crayfish and blind cavefish). These animals are extremely long lived with lifetimes of up to 50 years although 10 to 15 years is more likely in the study area (Poulson, personal communication). The low population density and low reproductive rates of

TABLE I-18 EXTERNALLY DERIVED IMPACTS ON CAVES (Modified from Stitt, 1976)

Action	Source	Cave Area[1] Affected	Nature of Impacts	Incidence[2]			Irreversible-[3] Irretrievable
				Time	Space	Degree	
1. Pollution							
A. Water							
1. Municipal Wastes	city sewage systems, or lack thereof	P	water polluted, odor & methane gas, affects ecosystem	L	LR	V	N-M
2. Industrial Wastes	factories, thru streams or direct seepage	PA	water polluted, odor & methane gas, heavy metals and affects ecosystem	SL	LR	V	N-M
3. Septic Tanks	homes, some small industrial	P	water polluted, odor & methane gas, highB.O.D., nutrients; affects ecosystem	M	LW	H	N-M
4. Agricultural Runoff	farm and pasture lands	P	siltation, pollution, odor & methane gas, upsets ecosystem, destroys lifeforms, increases nutrients, decreased D.O.	L	LW	M	Y-Y
5. Urban Runoff	city streets, parking lots	P	petroleum poisoning, siltation, upsets ecosystem	L	L	H	N-Y
6. Sinkhole Dumps Other Dumps Landfills	improper waste disposal	P	Water pollution remote and local	V	LR	M	N-Y
7. Gasoline Spills Toxic Compound Spills Pipeline Leakage	gasoline & chemical storage facilities, filling stations, parking lots, streets highways & pipelines	A	explosion hazard, destroys ecosystem, may damage formations	S	L	H	Y-Y
8. Sinking Polluted Streams	surface pollution sources	P	siltation, pollution, upsets ecosystem	V	L	M	N-Y
9. Thermal Pollution	power plants	PA	changes cave climate, upsets ecosystem	S	L	M	N-M

TABLE I-18 EXTERNALLY DEIRVED IMPACTS ON CAVES (Modified from Stitt, 1976) - Page 2

Action	Source	Cave Area 1 Affected	Nature of Impacts	Incidence 2			Irreversible-3 Irretrievable
				Time	Space	Degree	
10. Stream Tracing	technical	P	no known adverse effects when properly used;high beneficial impact when used for identifying sources of pollution	S	L	L	N-N
B. Air							
1. Surface Air Pollutants	cars,factories	A	increases solution rate of carbonate rocks	L	U	L	N-Y
2. Smoke	fires on surface, cigarettes	V	air particulate matter, deposition of film on surface of formation	S	L	L	N-Y
3. Inflammable Gases	gas pipelines, vegetation decay	V	potential explosion hazard	L	L	L	N-N
4. Airborne Herbicides and Pesticides	crop spraying	A	destroys ecosystem	L	L	M	N-Y
2. Hydrological Modification							
A. Surface Construction							
1. Roads	population proximity	A	diverts water sources,changes water source locations, dries out cave, destroys ecosystems, pollution(see above)	L	L	M	N-Y
2. Parking Lots	population proximity	A	stops infiltration, dries out rocks,destroys ecosystem, pollution,may cause rock falls	L	L	H	N-Y
3. Buildings	population proximity	A	stops infiltration,dries out cave,interupts water flow	L	L	L	N-Y
4. Stripping Topsoils	land leveling, recreational development	A	flooding, siltation	S	L	H	Y-Y

TABLE I-18 EXTERNALLY DERIVED IMPACTS ON CAVES (Modified from Stitt, 1976) - Page 4

Action	Source	Cave Area[1] Affected	Nature of Impacts	Incidence[2]			Irreversible-[3] Irretrievable
				Time	Space	Degree	
3. Vibration and Noise							
A. Blasting	contruction, mining	FV	formation breakage, rock fall may disturb bats	S	L	H	Y-Y
B. Vehicles	highways, railways	FS	formation breakage, rock fall, collapse, increased breakdown	L	L	H	N-Y
4. Limestone Mining and Quarrying	need for limestone	A	formation breakage, removal of cave	L	L	H	Y-Y

Notes

[1] Abbreviations used: P--phreatic (below the water table, i. e., the aquatic portion of the cave environment); V--vadose (above the water table); A--all of the cave; E--ecosystem; S--sediments and fill; F--formations and the surface of the rock.

[2] These are rough approximations only and incidence may be affected by local conditions. Abbreviations: Time: L--long term; M--medium term; S--short term; D--duration of activity. Space: L--local; R--remote; U--universal; W--widespread. Degree: L--low; M--medium; H--high; V--varies.

[3] Abbreviations: Y--yes; N--no; M--maybe.

TABLE I-10 EXTERNALLY DERIVED IMPACTS ON CAVES (Modified from Stitt, 1976) - Page 3

Action	Source	Cave Area 1 Affected	Nature Of Impacts	Incidence 2			Irreversible-3 Irretrievable
				Time	Space	Degree	
5. Agricultural	farming operations	A	siltation,infiltration changes,flooding,pollution	L	LW	H	N-Y
B. Water Projects							
1. Dams	need for flood control,power, and recreation	A	water level raised,inundation, increased recreational use	L	L	H	N-M
2, Channelization	drainage, flood control	A	water level lowered,flooding decreased,may affect ecosystem	L	L	H	Y-Y
3. Pumping of Groundwater	farming and ranching	P	water level lowered,possible collapse,increased siltation	D	LW	H	N-M
4. Capping Springs	need for water	A	reduction in water flow,upsets ecosystem	D	L	M	N-M
C. Deforestation	conversion from forest to other land use	A	siltation,flooding,increased stream turbidity,changes ecosystem	L	LM	H	Y-Y
D. Overgrazing	ranching and farming	A	siltation,flooding,pollution	L	L	M	N-Y
E. Siltation	deforestation, construction, agriculture,erosion, overgrazing	AP	fills passages with soil/ sand/clay/cobbles/wood,changes ecosystem	L	LW	H	N-Y
F. Flooding from External Causes	excess precipitation poor farming practice dams breaking,rapid snow melt	A	siltation,erosion,log jams and blocked passages,danger to visitors,provides nutrients for ecosystem	S	L	H	N-M

these species preclude any possibility of conducting bioassay tests. However, a much smaller number of individuals is necessary to test the levels of heavy metals accumulated in the tissues of the animals. The impacts of such a study would be much less on the blind troglobitic crayfish Orconectes pellucidus.

Sampling and analysis were conducted in order to study the ecological concentration of heavy metals in the cave crayfish Orconectes pellucides. Three specimens were collected at four sites: (1) Hick Spring entrance to the Hidden River complex, (2) L&N cave, (3) Parker River in Parker cave, (4) Crayfish Canyon in Parker cave. Detailed descriptions of the water quality at these sites are contained in the surface and subsurface water resources section. The major distinction between the sites is that only the Hick Spring site is subject to heavy metal pollution from the Horse Cave Treatment Facility.

Sample storage and analysis procedures are outlined in Appendix I. Samples were iced in the field, frozen overnight and transported to the lab on ice where they were stored in a freezer until analysis. Tissues were processed by a dry ashing technique and analyzed by atomic absorption spectrophotometry. Samples were analyzed for nickel, copper, zinc and chrome. Duplicate control samples were run on a common surface species of crayfish.

Test results are summarized in Table I-19. Results are presented both for extract concentration (mg/l) and tissue concentration (ug/gram wet weight). The heavy metal tissue concentration is calculated according to the formula:

$$\text{ug/g} = \frac{\underline{\text{mg/l of constituent in prepared sample}} \times \underline{\text{volume of prepared sample in ml}}}{\text{weight of wet sample in g}}$$

Test results were compared by means of single classification ANOVA's with equal sample sizes (Sokal & Rohlf, 1969). The initial overall ANOVA analysis indicated that there was not an overall difference in the tissue concentrations of nickel, zinc, chromium and copper between sites. The testing for zinc, chromium and copper, however, resulted in probability levels of between 10 and 5 percent (a = 0.10 & a = 0.05). In light of the fact that these tests were run with minimal replication, these results can be interpreted as indicating a borderline difference in metal concentrations between the sites for zinc, chromium and copper. Further testing was conducted by means of a a priori type comparison of the Hick Spring concentrations with the other three sites. Zinc, chromium and copper were all found to be significantly different at the 5 percent level (a = 0.05). Chromium and copper were found to be present in greater concentrations in the Hick Spring samples. A comparison of means indicates the chromium levels in Hick Spring samples are approximately 1.5 times those of the other sites while copper levels are approximately 1.6 times as high. Surprisingly, the comparisons of mean values indicated that zinc concentrations in Hick Spring samples were only about 53 percent of those found in the rest of the study area. The chromium and copper results appear to indicate an elevated level of chromium and copper in the animals collected at the Hick Spring site which is presumed to be due to the elevated levels in the Horse Cave Treatment Plant and Ken-Dec. No significant increase in nickel levels was detected and the interpretation of the zinc results is unclear. This testing and the conclusions are based on minimal data. The possible impact of a large scale sampling program on the population of the crayfish is acute. Results at this level indicate a detectible increase in tissue concentrations of chromium and copper at the Hick Spring site which is known to receive heavy metal pollution from the Horse Cave area.

Table I-19 . Wet weights (g), Analysis Results (mg/l) and Concentrations (ug/g wet weight) of Nickel and Zinc in Cave Crayfish tissue samples.

Site	#	Wet Wt. (g)	Nickel Result (mg/l)	Nickel Concentration (ug/g wet wt.)	Zinc Result (mg/l)	Zinc Concentration (ug/g wet wt.)
Hicks Spring	1	2.53	1.1	4.35	2.5	9.88
	2	2.52	1.3	5.16	2.9	11.51
	3	1.43	1.0	6.99	1.4	9.79
	$\bar{X}$	2.16	1.13	5.50	2.27	10.39
	s	0.5162	0.1247	1.1043	0.6342	0.7905
Parker River	1	3.99	1.2	3.01	4.7	11.78
	2	2.06	1.0	4.85	3.4	16.50
	3	2.17	1.2	5.53	3.7	17.05
	$\bar{X}$	2.74	1.13	4.46	3.93	15.11
	s	0.8850	0.0943	1.0645	0.5558	2.3653
Crayfish Canyon	1	1.98	1.3	6.57	6.3	31.82
	2	3.57	1.2	3.36	5.4	15.13
	3	2.58	1.8	4.88	7.2	19.53
	$\bar{X}$	2.71	1.43	4.94	6.3	22.16
	s	0.1847	0.2625	1.311	0.7348	7.0629
L & N Cave	1	1.29	1.2	9.30	2.5	19.38
	2	1.71	0.8	4.68	2.9	16.96
	3	2.08	1.2	5.77	5.7	27.40
	$\bar{X}$	1.69	1.07	6.58	3.7	21.25
	s	0.3227	0.1886	1.9718	1.4236	4.4618
Control	1	3.80	1.6	2.96	15.0	27.63
	2	4.72	1.4	2.33	15.0	25.00
	$\bar{X}$	4.26	1.5	2.645	15.0	26.32
	s	0.46	0.1000	0.3150	0.0000	1.3150

Table I-19. Wet weights (g), Analysis Results (mg/l) and Concentrations (ug/g wet weight) of Chromium and Copper in Cave Crayfish tissue samples.

Site	#	Wet wt. (g)	Chromium Result (mg/l)	Chromium Concentration (ug/g wet wt.)	Copper Result (mg/l)	Copper Concentration (ug/g wet wt.)
Hicks Spring	1	2.53	1.1	4.35	15.9	62.85
	2	2.52	1.6	6.35	17.8	70.63
	3	1.43	0.9	6.29	8.0	55.94
	X̄	2.16	1.2	5.66	13.9	63.14
	s	0.5162	0.2944	0.9290	4.2434	6.0007
Parker River	1	3.99	1.1	2.76	7.2	18.05
	2	2.06	1.0	4.85	6.5	31.55
	3	2.17	0.9	4.15	6.7	30.88
	X̄	2.74	1.0	3.92	6.8	26.83
	s	0.8850	0.0816	0.8686	0.0075	6.2121
Crayfish Canyon	1	1.98	0.8	4.04	12.9	65.15
	2	3.57	0.8	2.24	6.9	19.33
	3	2.58	1.1	2.98	16.0	43.41
	X̄	2.71	0.9	3.09	11.9	42.63
	s	0.1847	0.0004	0.7387	3.7774	18.7141
L & N Cave	1	1.29	0.6	4.65	8.1	62.79
	2	1.71	0.6	3.51	7.3	42.69
	3	2.08	1.0	4.81	8.7	41.83
	X̄	1.69	0.73	4.32	8.0	49.11
	s	0.3227	0.0013	0.5788	0.5735	9.6823
Control	1	3.80	1.6	2.95	28.0	51.58
	2	4.72	1.5	2.50	28.0	46.67
	X̄	4.26	1.55	2.73	28.00	49.13
	s	0.46	0.0500	0.0026	0.0000	2.4550

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12. TERRESTRIAL ECOLOGY

The terrestrial environment of the study area has been modified. The clear cutting of forests and subsequent farming of suitable areas has determined the current patterns of floral and faunal distributions. The degree of agricultural modification is associated with the severity of the local topography. Relatively flat areas have been clear cut while areas with steep slopes have been selectively cut. A few areas of extreme relief have not been disturbed. The description of the terrestrial communities has been organized into floral and faunal sections. Each section includes a description and species list for the communities.

Floral Communities

Most of the study area can be classified as agricultural or forest land. Total farm areas account for 79% of the study area. This includes land in and out of cultivation, which is classified as agricultural. Forest area is based on aerial photo interpretation and accounts for almost 43% of the land area. The best estimate of land under active cultivation is the non-forest area minus the non-farm area. The estimated cultivated area for the three-county area is 276,842 acres or over 36% of the total land area.

Agricultural lands include virtually all rural areas of the Sinkhole Plain and Glasgow Uplands which are not either knobs or marshes. Additional agricultural lands are found in the Chester Cuesta and Escarpment where local topography permits its development. The important crops of the region include corn, sorghum, wheat, hay, tobacco and pasture (Table I-20). Cattle and tobacco are the major cash crops of the area.

The forests of the Mammoth Cave EIS study area have been the subject of detailed study within the Mammoth Cave National Park. As the park was originally established with purchases of small private farms, the results and conclusions of the park forest studies can be assumed valid for forest areas outside the park of the Western Mesophytic Forest Region of Braun (1950). This region represents a mosaic of elements from the Mixed Mesophytic Region and the Oak-Hickory Forest Region. The most current and detailed study of the Mammoth Cave forests is that of Faller (1975). He identifies three major plant community types within the area: Mixed Woods Association, Floodplain Association and an Upland Oak Association. Within each of these associations are several subtypes. In addition, there are extensive tracts of old field communities developing on the abandoned farms of the Mammoth Cave Park. These associations and subtypes are established along age, moisture and topographic gradients.

Mixed Woods Association:

The Mixed Woods Association is the most widely distributed association and is characterized by several species sharing dominance (Table I-21). Indicator species for this forest type include northern red oak, white oak, tuliptree, sugar maple, red maple and formerly American chestnut. Four subtypes of the Mixed Woods Association are identified within the study area: xeric, intermediate, mesic and hemlock. Xeric stands are dominated by white oak, pignut hickory and chestnut oak. Intermediate stands are dominated by black oak, white oak, tuliptree, and northern red oak. American beech, tuliptree and white oak are the leading dominants of the mesic stands. The hemlock subtype is dominated by hemlock, beech, and tuliptree.

TABLE I-20 SURVEY RESULTS ON CURRENT FARM ACREAGE COMMITMENTS TO ASSORTED CROPS.

Crop	County		
	Barren	Edmonson	Hart
Corn			
Grain	16,498	3,574	8,533
Silage	3,649	298	1,912
Sorghums			
Grain	21	20	16
Silage	343	25	78
Wheat	1,066	78	217
Other small grains	1,426	—	241
Hay	30,912	8,326	19,530
Tobacco	4,033	666	2,844
Woodland			
Pastured	16,343	7,028	15,167
Not pastured	14,386	11,372	22,950

Source: U.S. Bureau of the Census, 1972.

TABLE I-21 DOMINANT TREE SPECIES FOR FOUR PLANT ASSOCIATIONS WITHIN THE STUDY AREA (after Faller, 1975)

MIXED WOODS	
Quercus velutina	Black Oak
Quercus alba	White Oak
Quercus rubra	Red Oak
Fagus grand folia	Beech
Quercus prinus	Chestnut Oak
Juniperus virginiana	Red Cedar
Liriodendron tulipifera	Tulip-Tree
FLOODPLAIN STANDS	
Platanus occidentailis	Sycamore
Fraximus pennsylvanica	Green ash
Acer negundo	Box Elder
Acer saccharinum	Sugar Maple
UPLAND STANDS	
Quercus alba	White Oak
Quercus velutina	Black Oak
Pinus virginiana	Scrub Pine
Nyssa sylvatica	Sour-Gum
Quercus rubra	Red Oak
OLD FIELDS	
Juniperus virginiana	Red Cedar
Pinus virginiana	Scrub Pine

The xeric, intermediate and mesic subtypes, are obviously found across a moisture gradient. These mixed stands are found throughout the Park on the slopes of the solution valleys and streams associated with the Green River. The density of the herbaceous cover was intermediate in the Mixed Woods Association with the Floodplain Association being more dense and the Upland Association being less dense. No one species dominates the groundcover. In addition, there is minimal overlap between the herb components. Species commonly associated with mixed woods include the swamp jack-in pulpit, trout lily, goldenseal, and foamflower.

The most consistent woody species of the Mixed Woods Association, the flowering dogwood, is present in the herb and shrub layers and the sapling size class. Woody species in the herb layer also included sugar maple, red maple, redbud and Sassafras. Shrub layer woody species include redbud, spicebush and American Beech. The other dominants include sugar maple, red maple, beech and white oak.

Hemlock Subtype

The Hemlock Subtype represents a relict tertiary forest and is extremely limited in the study area. Stands are found in remote areas with extreme topography. The eastern hemlock (Tsuga canadensis) is the dominant tree species, secondary species include the beech and tuliptree. In addition, American Holly yellow birch and cucumber and umbrella magnolias are often associated with the Hemlock Subtype. Sweetgum and tree-of-heaven are found in low density.

Floodplain Association

Floodplain communities are naturally associated with the Green River. The floodplain area may be subdivided into floodplain proper, bottoms, and terraces. The bottoms behind a natural levee are subject to annual flooding. Terraces are rarely flooded. The bottoms and terraces were intensively farmed before inclusion in the Park. However, recovery has been rapid. In addition, several large islands also support vegetation of the Floodplain Forest. Within the Floodplain Association, there is a distinct banding of community subtypes from the floodplain proper through the terraces. The islands also exhibit this community banding with an additional concentration of the herbaceous community at the upstream end of the islands. This accumulation is related to the developmental pattern of the islands in which material is accumulated at the upstream end and lost at the downstream end. The larger islands appear to be relatively stable as indicated by the nearly total absence so willow and cottonwood.

There are four leading dominants in the Floodplain Association (Table I-21). There is a large variation in dominants between stands. This variation is related to surface elevation differences between the islands. The sapling stratum and shrub layer are poorly developed in the Floodplain Association. The herbaceous component of the Floodplain is relatively distinct from other associations. Several plants are restricted to the bottom lands of the floodplain. The herb stratum of the floodplain flowers conspicuously from July through September.

Upland Woods Association

The selective cutting of valuable tree species in the Upland Association has severely limited the area of mature seral stages. This association is dominated by oaks (Table I-21). Species dominance is segregated by substrate type. Upland stands are usually less diverse than mixed wood slope stands and show a shift in less important species to more xeric species. This is particularly notable for the hickories (Carya spp.) In addition, upland stands are more open than the mixed woods and have a reduced herbaceous flora. The herb stratum is again distinct from the other associations. Herbaceous species which are restricted to the upland woods include bluets, spotted wintergreen and larger tickseed. The woody species component of the herb, shrub and sapling strata is similar to that of the mixed woods.

Old Field Succession

A study of secondary succession of Old Field Systems within Mammoth Cave National Park indicates that forest recovery is proceeding at variable rates depending upon substrate and prior land management (Faller, 1975). The slowest recovery is on the abandoned farmlands of the Mammoth Cave Plateau. Old Field communities are located on level sites within the floodplains, upland plateaus and valleys. Floodplains show the quickest recovery with associations approaching mature status after 35 to 45 years. The upland plateau Old Field support more woody vegetation at this time than similar communities in the large valleys. Upland Old Field seres are dominated by eastern red cedar and Virginia Pine. The dominant species of the Upland Association are not yet established in the upland Old Fields. This is partially due to the restocking of Old Fields with pine as a conservation measure. Areas of Mixed Woods Association were not extensively forested. Selective cutting has led to a detectable change in species dominance.

A complete floral list is included in Appendix I. This list was obtained from Faller (1975) and includes species collected by Faller and by Davies (1954).

Faunal Communities

Faunal lists for the Mammoth Cave EIS study area are contained in Appendix I. These lists are based primarily on National Park Service information obtained through the Mammoth Cave National Park Library. Additional information was obtained through various publications on the fauna of Kentucky. The complex plant communities of the study area and the protection afforded by Mammoth Cave National Park support a diverse animal community. The mosaic of farm and forest land produces a large edge effect which further enhances the area in terms of wildlife habitat. Wildlife lists include Reptiles, Amphibians, Mammals, Birds and Invertebrates (Snails). Bird species lists are listed as to their abundance (rare, common, abundant) in the National Park.

13. RARE AND ENDANGERED SPECIES

The rare and endangered flora and fauna of the Commonwealth of Kentucky are currently protected by Federal regulations. In the past, protection was also afforded by state law. Recent legislative action, however, has removed the state regulations.

State and Federal lists were reviewed for species with confirmed presence in the area and for those species whose general habitat and range indicate possible presence in the study area. Confirmed and suspected rare and endangered species are summarized for the mammals, birds, amphibians, reptiles, fish, invertebrates and flora of the study area (Table I-22). Exact locations are not available for most of the protected species. The symbols used on Table I-22 are explained below:

FEDERAL: Species protected under the Federal Endangered Species Act of 1973

STATE: Species formerly protected under state law in the Commonwealth of Ky.

C: Confirmed presence in study area

S: Suspected presence in study area

E: Endangered

T: Threatened

R: Rare

Definitions - The terms Endangered and Threatened are officially defined in the Federal Endangered Species Act of 1973 as follows:

Endangered Species - "Any species in danger of extinction throughout all or a significant portion of its range other than a species of the class Insecta determined by the Secretary of the Interior to constitute a pest whose protection under the provisions of this act would present an overwhelming and overriding risk to man."

Threatened Species - "Any species which is likely to become an endangered species within the foreseeable future."

The state term "Rare" implies that the species is uncommon and is roughly equivalent to the Federal Threatened status.

Parantheses have been used to indicate species which are being reviewed or recommended for the indicated status.

TABLE I-22. RARE AND ENDANGERED SPECIES OF THE STUDY AREA

	FEDERAL		STATE	
	C	S	C	S
MAMMALS				
Myotis austroriparius-Southeastern Bat			R	
Myotis grisescens-Gray Bat	E		E	
Myotis leibii-Small Footed Bat			R	
Myotis sodalis-Indiana Bat	E		E	
Sorex longirostris-Bachman's shrew				R
Zapus hudsonium-Meadow Jumping Mouse				R
BIRDS				
Dendrocopus borealis-Red-cockaded Woodpecker	E		E	
Haliaetus leucocephalus leucocephalus-Southern Bald Eagle	E		E	
Pandion haliaetus-Osprey			R	
AMPHIBIANS AND REPTILES				
Elaphe guttata-Corn Snake			E	
Lampropeltos calligaster calligaster-Prairie King Snake			R	
Lampropeltis doliata doliata-Scarlet Kingsnake			R	
Masticophis flagellum flagellum-Eastern Coachwhip Snake			E	
Pituophis melanoleucuc-Northern Pinesnake			R	
Tantilla coronata coronata-Southeastern Crowned Snake			R	
Eumeces anthracinus anthracinus-Northern Coal Skink			E	
Hemidactylium scutatum-Four-toed Salamander				R
Ophisaurus attenuatus longicaudus-Slender Glass Lizzard			R	
FISH				
Percina macrocephala-Longhead Darter			R	
Typhlichthys subterraneus-Lesser Blindfish			(R)	
Amblyopsis spelaea-Mammoth Cave Blindfish			(R)	
INVERTEBRATES				
Lampsilis orbiculata orbiculata-Pink Mucket Pearly Mussel	E		E	
Pleurobema plenum-Rough Pigtoe Pearly Mussel	E		E	
Palemonies ganteri-Mammoth Cave Shrimp			(E)	
FLORA				
Apios priceana-Groundnut		T		
Arabis perstellata var. *perstellata*-Rockcress	E			
Aureolaria patula		T		
Castanea dentata-Chestnut			E	
Cypripedium calceolus var. *pubescens*-Yellow Lady's Slipper			R	
Gentiana andrewsii-Bottle Gentian			R	
Gentiana decora-Showy Gentian				
Gentiana quinquefolia-Stiff Gentian				R
Hydrastis canadensis-Goldenseal			E	
Hypericum sphaerocarpum var. *turgidum*-St. John's -wort		T		

TABLE I-22. RARE AND ENDANGERED SPECIES OF THE STUDY AREA (Cont'd.)

	FEDERAL		STATE	
	C	S	C	S
FLORA (Cont'd.)				
Leavenworthia exigua var. *laciniata*		E		
Leavenworthia torulosa		T		
Lesquerella globosa-Roadside weed	T			
Panax quinquefolium-Ginseng			T	
Phlox bifida var. *stellaria*-Sand Phlox	T			
Populus heterophylla-Downy Popular				R
Trifolium reflexum-Buffalo clover			R	
Trillium nivale-Dwarf White Trillium				R
Viola egglestonii-Violet		T		

PART C

MAN-MADE ENVIRONMENT

1. POPULATION CHARACTERISTICS

The Mammoth Cave EIS study area encompasses portions of three predominantly rural counties, Barren, Hart and Edmonson. Since there are no nearby urban population centers, it is not included in any Standard Metropolitan Statistical Area (SMSA). In this rural setting there are four population centers, the towns of Munfordville, Horse Cave, Cave City and Park City. The Mammoth Cave National Park may also be considered a population center during the summer months because of the large number of tourists visiting the park. "Cave Country" visitation, in addition, significantly increases the summer populations in the towns of Horse Cave, Cave City and Park City as they provide tourist accommodations.

The study area outside the towns is only sparsely populated, about 30-40 people per square mile. Because the population density is so low, public waste water collection and treatment facilities in these areas are considered impractical. For this reason, only the populations of Munfordville, Horse Cave, Park City and Cave City as well as the seasonal population of Mammoth Cave National Park are considered pertinent to this study.

Since there are no defined surface drainage basins in the sinkhole plain, attempts to disaggregate populations in the study area according to drainage sub-basins are considered inappropriate. Population is already disaggregated to the four separate municipalities and the National Park. In addition, these existing population centers are also considered to be the bases for any future development in the study area. Therefore, population projections for this study are made by population center rather than drainage basin.

In 1970, the Kentucky Program Development Office (KPDO) developed separate population projections for the municipalities of Horse Cave, Cave City, Park City and Munfordville. Starting with the 1970 census populations, the KPDO provides projections for the years 1975, 1980, 1990 and 2000 (Table I-23). For comparison, past population trends are included in Table I-24. There are no OBERS population projections for these municipalities. OBERS only provides information at the county level in rural areas.

The 1975 populations for each municipality were estimated by the U.S. Department of Commerce Bureau of the Census and appear in Table I-23. In addition, 1977 population estimates are developed for this report (Detailed development appears in Appendix I). These present population estimates for Horse Cave, Cave City and Park City are developed primarily from number of water customer connections with some consideration given to water consumption data. The main assumption required is that the ratio of population to water connections, as calculated from 1970 census population and approximate number of connections, is nearly constant. Fair, Geyer and Okum (*Water and Wastewater Engineering Vol I*, pg. 5-7) report that this ratio is typically about 3:1. This lends some support to the assumption, since the 1970 ratios for Park City, Horse Cave and Cave City are 2.8, 2.9, and 3.1 respectively.

TABLE I-23. KENTUCKY PROGRAM DEVELOPMENT OFFICE POPULATION PROJECTIONS WITH 1975 AND 1977 POPULATION ESTIMATES

Population Center	1970 Census	1975	1977 by graphical interpolation	1980	1990	2000
Horse Cave	2,068	2,114 *(2,115)	2,200 **(2,420)	2,362 (2,580)[1]	2,712 (2,960)[1]	3,093 (3,380)[1]
Cave City	1,818	1,955 *(2,094)	1,990 **(2,180)	2,015 (2,207)[1]	2,230 (2,440)[1]	2,470 (2,700)[1]
Munfordville	1,233	1,280 *(1,306)	1,300 **(1,680)	1,342 (1,700)[1]	1,473 (1,860)[1]	1,614 (2,040)[1]
Park City	576	592 *(553)	600 **(640)	628 (660)[1]	672 (750)[1]	723 (850)[1]

* ( ) 1975 U.S. Dept. of Commerce Bureau of the Census Estimate.
** ( ) 1977 Population estimate based on approximate number of water customers. Developed by GFC&C, Inc.
[1] ( ) Projections developed by GFCC, Inc.

Source: Comprehensive Water and Sewer Report. 1973, BRADD.

TABLE I-24. POPULATION TRENDS OF COUNTIES AND INCORPORATED CITIES 1940-1970

County/City	1940	% Change	1950	% Change	1960	% Change	1970	Land Area in Square Miles	Population Per Square Mile 1960	Population Per Square Mile 1970
Barren	27,559	3.3	28,461	-0.6	28,303	1.3	28,677	468	60.4	61.3
Cave City	960	16.6	1,119	26.7	1,418	28.2	1,818			
Park City	354	26.6	448	10.9	497	14.1	567			
Edmonson	11,344	-17.3	9,376	-13.8	8,085	8.2	8,751	298	27.1	29.4
Hart	17,239	-11.1	15,321	-7.8	14,119	-1.0	13,980	420	33.6	33.3
Horse Cave	1,278	17.3	1,545	13.2	7,780	16.2	2,068			
Munfordville	832	6.9	894	22.7	1,157	6.6	1,233			
BRADD Totals	182,660	-2.2	178,646	-4.6	170,463	9.2	186,279	3,958	76.6	81.2

Source: 1978 BRADD Data Book

Developing a 1977 population estimate for Munfordville is somewhat more complicated since some populations served by municipal water are not within the incorporated city limits and others have been annexed since 1970. In addition to water customer connections and water demand, housing units and actual apartment population counts are also used in developing population estimates for the Munfordville area. For the purposes of this report, Munfordville refers to the Munfordville area which includes the incorporated limits as well as those areas presently served by municipal water and/or sewer.

Population projections are developed for Cave City, Horse Cave and Munfordville based on the 1977 population estimates and KPDO projection growth rates. Park City population projections are developed independently, however, because of the anticipated rapid growth due to the construction of the proposed Mammoth Cave National Park staging area at Union City which will provide Park City with the most convenient access to the National Park. For Cave City, Horse Cave and Park City, the KPDO 1980 projection is adjusted upward to reflect the difference between the 1977 estimated and KPDO projection. Growth is then assumed to continue at the same rate as projected by KPDO. Park City growth, however, is expected to be best approximated by a geometric series, since ever increasing growth is anticipated during the next twenty-five years with the development of the Park Master Plan. The population projections for the municipal population centers appears in Table I-25. A detailed methodology for formulating these projections is provided in Appendix I.

Although there is a small permanent staff population at the Mammoth Cave National Park, it is considered to be insignificant compared to the "population" of the park during the summer tourist season. During the peak months of July and August, an estimated 11,000-people/day visit the National Park. This figure includes only visitors that use park facilities. This does not include "drive-through" visitation. These peak seasonal populations are considered to be of most importance in providing water and sewerage services in the area even though a smaller tourist population is present throughout the year.

The National Park Master Plan provides visitation projections to the year 2000. However, visitation during the past 5 years indicate that these projections may be somewhat optimistic. Newer projections developed for a transportation plan presently being prepared for the Park estimate daily average cave visits to be 7,100-7,800 during July-August of 2000. This represents a total of about 14,200-15,600 park visitors. These projections also indicate that peak cave visitation during the summer months is expected to reach 10,600-11,700 cave visits per day on many week-ends and holidays.

Using these projections as the year 2000 estimate, linear growth is assumed from the present to generate estimates for intermediate years. These Park visitation estimates are indicated in Table I-26.

2. LAND USE

The present land use pattern in the study area reflects the rural characteristics of the area. Most of the study area land uses fall within the categories of agricultural, forested or vacant land use. The four municipalities of Munfordville, Horse Cave, Cave City and Park City are all small communities which serve as centers of residential, commercial and industrial land use in the study area.

TABLE I-25. POPULATION PROJECTIONS FOR MUNICIPAL POPULATION CENTERS

Population Center	1980	1990	2000
Horse Cave	2,580	2,960	3,380
Cave City	2,207	2,440	2,700
Munfordville (Area)	1,700	1,860	2,040
Park City	660	750	850

Source: Gannett Fleming Corddry and Carpenter, Inc.

TABLE I-26 MAMMOTH CAVE NATIONAL PARK PROJECTED VISITATION (VISITORS/DAY)

Year	Average Daily Cave/Peak Cave Visits July-August Visitation	Average Daily Total /Peak Park Park Visits July-August Visitation
1980	5,200/7,700	10,400/15,400
1990	6,400/9,500	12,800/18,900
2000	7,500/11,100	15,000/22,200

Sources: Year 2000 projections developed by William S. Pollard, Consultants, Memphis, Tennessee.

Gannett Fleming Corddry and Carpenter, Inc.

The major influences on land use in the study area are Mammoth Cave National Park and Interstate 65. Mammoth Cave National Park comprises over 51,000 acres of land. The park is owned and operated by the U.S. National Park Service. As stated in the Final Master Plan for Mammoth Cave National Park the management objective of the park "...is to perpetuate the integrity and diversity of geologic features and life systems that are associated with the caves, and the aquatic and terrestrial environments, for these have aesthetic, recreational, educational and scientific values to man."

Visitations to the park have increased dramatically over the past 25 years. In 1973 cave visitations reached an all time high of 675,167 persons. Increased visitations to the park have also influenced the economy and land use of the area by increasing the dependency on tourism as a major source of employment and income to the area.

The major impact of the park and increasing visitation has been the proliferation of tourist related activities in the area such as motels, restaurants, service stations, and camping grounds. Most of this activity has focused around the I-65 interchange at Cave City where a variety of commercial activities related to the park's tourism have been developed. Other minor commercial activity has developed at the I-65 interchanges at Cave City and Horse Cave.

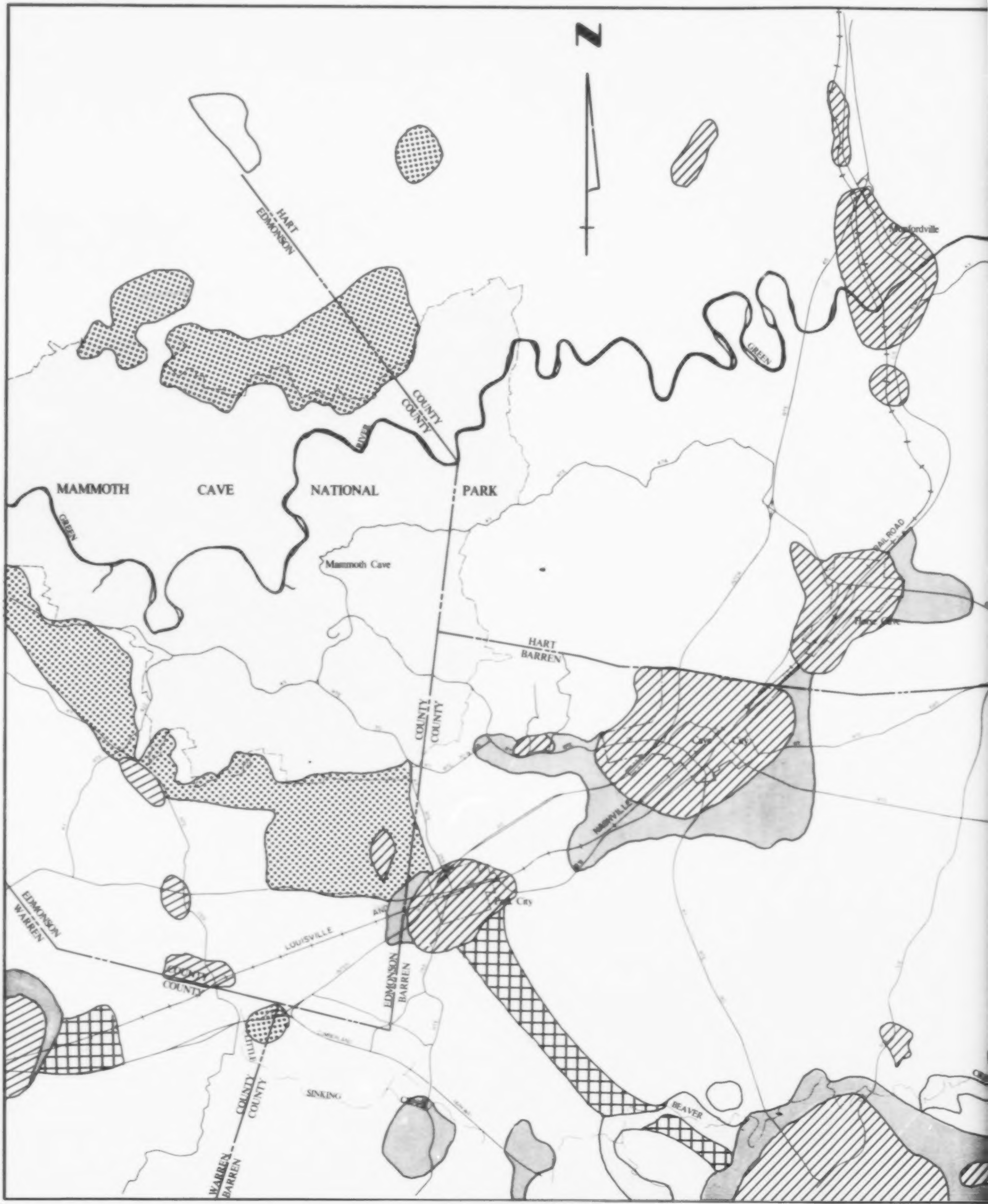
There is little existing land use planning or zoning activity in the study area. There is no planning and zoning commission in either Hart or Edmonson Counties. Therefore, there is no comprehensive plan for either county nor are there any zoning or subdivision regulations in either county. In Barren County there exists a Joint City-County Planning Commission which includes Barren County and the cities of Cave City, Park City, Hiserville, and Glasgow. There is a county comprehensive plan but regulatory measures such as zoning, subdivision regulations, and building and housing codes are only enforced within the city of Glasgow.

Figure I-68 is a generalized map of existing and future land use in the study area. This map is based upon a land use map developed by the Barren River Area Development District in their Comprehensive Sewer and Water Plan.

Future land use development is expected to reflect the influence of Mammoth Cave National Park. If use of the park increases, as expected, there will be demands for additional tourist related activities throughout the area. A major impact on future land use in the area would be the national park's plan to construct a new staging area at a place called Union City on the periphery of the park. This site is 3/4 mile inside the main park entrance at Chaumont, the name of the junction of Mammoth Cave Parkway (Ky-255) from Park City and Ky-70 from Cave City. At the staging area the national park would construct a terminal building from which visitors would board transit vehicles for cave trips, trail lands for hikes and the sightseeing boat trip on the Green River.

Location of this staging site will have a significant influence on the I-65 interchange at Park City since this exit would be the closest to the proposed terminal and staging area. This could very well result in a proliferation of motels, restaurants, service stations and camping sites in the area between Park City and the national park entrance.

Regardless of the influence of the national park, future growth in the study area is not expected to experience any dramatic changes.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COUNTY
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Munfordville
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RIVER
MAMMOTH
CAVE
NATIONAL
PARK
GREEN
Mammoth Cave
RAILROAD
Horse Cave
HART
BARREN
COUNTY
COUNTY
Cave City
NASHVILLE
Park City
EDMONSON
WARREN
LOUISVILLE
AND
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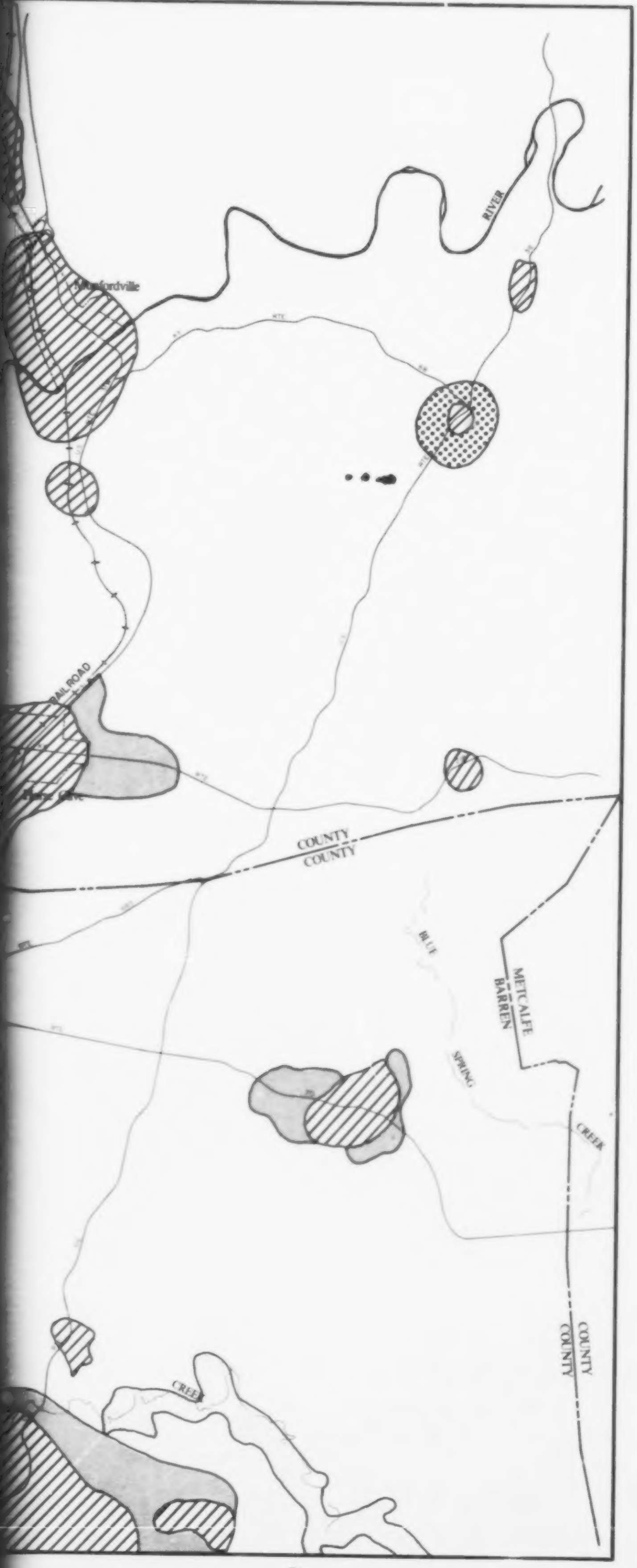

Munfordville
RIVER
RAILROAD
Horse Cave
COUNTY
COUNTY
BLUE
SPRING
CREEK
METCALFE
BARREN
CREEK
COUNTY
COUNTY

LEGEND

░	MAMMOTH CAVE NATIONAL PARK
▨	EXISTING RESIDENTIAL / COMMERCIAL / INDUSTRIAL
☐	EXISTING PUBLIC / SEMI-PUBLIC
☐	EXISTING AGRICULTURAL, WOODLAND AND VACANT
▒	FUTURE RESIDENTIAL
⣿	FUTURE COMMERCIAL
▦	FUTURE INDUSTRIAL
☐	FUTURE PUBLIC / SEMI-PUBLIC
☐	FUTURE AGRICULTURE, WOODLANDS AND VACANT

SOURCE: THE COMPREHENSIVE WATER AND SEWER PLAN. BARREN RIVER AREA DEVELOPMENT DISTRICT.

FIGURE I-68

MAMMOTH CAVE AREA
201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

GENERALIZED EXISTING AND FUTURE LAND USE

12,000 6000 0 12,000 24,000
Scale In Feet

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia

B

Residential - Residential land use in the study area will be characterized by residential growth outside of the incorporated cities. This growth will continue to occur in scattered low density developments adjacent to the existing urbanized areas and along major transportation routes.

Commercial - Major commercial growth will occur on the roads leading into Mammoth Cave National Park. This would include Ky-70 from Cave City and Ky-255 from Park City. This growth will include mostly tourist oriented businesses. The impacts of the new national park staging area at Chaumont will significantly affect commercial development along Ky-255 from Park City. Other commercial facilities are expected to be located on the outer fringes of the municipalities in the study area.

Industrial - There is not expected to be any major industrial development in the study area as the area's economy becomes increasingly dominated by the tourist business. Industries that are located in the area will select sites close to interchanges on I-65 or to railway facilities of the L&N Railroad.

Public/Semi-Public - This category includes land uses such as recreation and open space, public facilities and transportation facilities. The major existing public facility in the study area is the Mammoth Cave National Park.

Agriculture, Woodlands and Vacant - This land use is now and will continue as the major land use in the study area. However, as farming and forestry activity dwindles, more and more land will convert to vacant status. In addition, this land use will be encroached upon by other land uses as there are demands for additional residential, commercial or industrial land.

3. ECONOMIC CONDITIONS

The entire study area has for many years had an economy dominated by agriculture or agriculturally related employment. However, agriculture as a focal point of employment in the study area has given way to manufacturing as the major employer in the study area. However, during the period from 1950 to the present the area has become less dependent upon agriculture with declining agricultural employment, fewer farms and fewer amounts of land available for farm land activity.

Although the area has been changing its economic base from dependence upon agriculture to increasing dependence on manufacturing and tourism related services, the area continues to suffer from high unemployment and low per capita incomes.

Employment

The employment data for the study area is illustrated in Tables I-27 and I-28. Both agriculture and manufacturing remain as the largest employment categories in the study area. In 1976 manufacturing led the three county study area with 5,132 employees followed by 4,346 employees in the agriculture category.

However, within the individual counties in the study area there are some significant differences. Barren County has the study area's highest employment with a 1976 employment total of 15,845. Manufacturing is the leading employer in the county, followed by agriculture and wholesale and retail trade. Agricultural employment over the 6 year period from 1971-1976 has actually shown some

TABLE I-27.

EMPLOYMENT DATA BY COUNTY 1971 - 1976

County/Year	Total	Agriculture	Non-Agriculture	Manufacturing
Barren				
1971	12,340	2,550	9,790	3,000
1972	13,320	2,350	10,970	3,460
1973	16,230	3,110	13,120	4,270
1974	15,889	2,824	13,065	4,464
1975	14,553	2,667	11,886	3,658
1976	15,845	2,880	12,956	4,056
Edmonson				
1971	1,890	590	1,300	380
1972	2,320	560	1,760	9
1973	1,860	340	1,520	12
1974	2,778	268	2,510	335
1975	3,056	252	2,804	388
1976	3,256	273	2,983	428
Hart				
1971	4,710	1,590	3,120	590
1972	4,730	1,520	3,210	640
1973	5,800	1,640	4,160	680
1974	5,761	1,510	4,251	684
1975	5,635	1,427	4,208	592
1976	5,812	1,541	4,271	648

Source: BRADD Integrated Program Design - June, 1977 increases. Manufacturing has been subject to many fluctuations in employment levels, but it remains the county's leading employment category. Services have also become a large employer as the demand for tourism related services increase. In 1976 there were 1,510 persons employed in services.

Edmonson County had a 1976 total employment of 3,256 persons. Manufacturing is also the leading employer with 428 employees, followed by services and agriculture, each with 252 employees in 1976. Agricultural employment in the county has declined significantly over the past 6 years from 590 in 1971 to 273 in 1976. Manufacturing and services have both had significant increases with services increasing by over 100 percent. Once again this reflects tourism associated with Mammoth Cave National Park.

In Hart County the leading employer remains agriculture. In 1975, agricultural employment in the county was 1,427 persons followed by wholesale and retail trade with 709 employees in 1976 and manufacturing with 648 employees in 1976.

Unemployment in the study area has been relatively insignificant in Barren and Hart Counties. However, Edmonson County has experienced significant unemployment. Table I-29 provides unemployment trends over the period from 1965-1975. Barren and Hart County unemployment rates are fairly consistent with regional, Kentucky and U.S. unemployment rates. However, Edmonson County has had unemployment rates which are consistently above regional, state and national levels. These rates have varied from a high of 20.0% in 1970 to a low of 7.6% in 1974.

Income

Income data is a good indicator of the economic status of a particular area. Table I-30 presents income data for the three counties in the study area and the BRADD region. Additional per capita personal income data for Kentucky and the United States are shown for comparison purposes. Per capita personal income for the study area is well below Kentucky and U.S. levels. This is due to the large number of persons in the agricultural and manufacturing employment categories. These are both relatively low paying areas. In addition, the area of services associated with tourism can be expected to grow and are also low income employment categories.

Table I-31 presents Median Family Income for the counties in the study area. This table continues to verify that incomes in the study area are well below national levels. Barren County has the highest median family income, followed by Hart and Edmonson County. However, in 1969 Edmonson County had a higher median family income than Hart County.

Table I-32 presents Labor Force Characteristics for the three counties in the study area. These characteristics present some insight into the size of the area's work force and the participation rates. Labor force size has increased during each period in the table for Barren and Edmonson County. However, Hart County had a decrease from 1960 to 1970 but this has again increased in 1975. The percent of persons in the labor force employed and the actual numbers of persons employed have increased for all three counties during the period from 1960 to 1975.

TABLE I-29.
UNEMPLOYMENT TRENDS, 1965 - 1975

COUNTY	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
BARREN	4.4	4.0	5.4	4.9	4.5	5.0	4.7	3.5	3.4	4.5	9.1
EDMONSON	18.1	18.3	16.7	14.8	14.9	20.0	18.1	20.7	17.3	7.6	10.1
HART	4.5	3.5	5.3	4.6	4.2	5.6	5.3	4.8	4.2	4.4	7.9
BRADD	4.7	4.3	5.3	4.5	3.9	5.4	6.0	4.7	5.6	4.6	8.3
KY.	5.9	5.2	5.1	4.6	4.2	4.8	5.3	4.6	3.7	4.5	7.3
U.S.	4.5	3.8	3.8	3.6	3.5	4.9	5.9	5.6	4.9	5.6	8.5

Source: BRADD Integrated Program Design - June, 1977

TABLE I-30.
TOTAL PERSONAL AND PER CAPITA INCOME
1965 - 1973

County	Total Personal Income (In Thousands)					Per Capita Personal Income				
	1965	1967	1969	1972	1973	1965	1967	1969	1972	1973
Barren	$54,111	$62,239	$74,869	$95,000	$110,100	$1,779	$2,036	$2,530	$3,227	$3,668
Edmonson	8,612	10,687	13,362	18,000	21,600	1,069	1,320	1,760	1,914	2,364
Hart	21,987	24,693	28,493	37,000	39,800	1,618	1,808	2,090	2,545	2,713
BRADD	304,396	357,250	430,056	568,000	662,600	1,659	1,938	2,401	2,932	3,141
Kentucky								2,894		4,050
U.S.								3,733		5,041

Sources: BRADD Integrated Program Design, June 1977

Industrial Resources, Cave City, Kentucky Department of Commerce, 1976

TABLE I-31.

MEDIAN FAMILY INCOME (DOLLARS)

	1949	% Change 1949-59	1959	% Change 1959-69	1969
Barren County	1,374	99.3	2,738	111.7	5,795
Edmonson County	1,095	86.5	2,042	149.8	5,101
Hart County	1,221	99.5	2,436	103.8	4,957
BRADD Region	1,177*	108.6	2,455*	119.2	5,383*

U.S. Median Family Income

1950 - $3,083	1960 - $8,657	1970 - $9,433

* Represents the average of the median family incomes for the ten county region.

Source: Comprehensive Water and Sewer Plan, Barren River Area Development District, July 1973.

Retail Business Trends

Tables I-33 and I-34 present information on retail business trends in the three county study area in terms of both the number of establishments and total sales volume. These include establishments such as food stores, lumber, general merchandise, automotive dealers, automobile service stations, wearing apparel, furniture, restaurants, drug stores and other retail establishments.

A review of the table on number of establishments indicates that the three county study area has had a net loss of 5 retail establishments during the period from 1948 to 1972. Barren County is the only county which has shown a net increase, probably due to growth in Glasgow and development associated with tourism at the national park. Edmonson and Hart counties have both had not losses of business establishments during the period. Retail sales volumes have increased throughout the period but much of this is probably caused by inflation during the period from 1948 to 1967. Sales increased from 25,000 in 1948 to 57,110 in 1968.

From this information it would appear that the major influence of increased visitation at the national park has been within Barren County. The county has recovered from a 6.9% loss of retail establishments from 1963-1967 to show a 6.2% increase in retail establishments during the period from 1967 to 1972. It appears that the construction of I-65 or increased visitation at the national park have had no influence on retail activity in either Hart or Edmonson Counties.

4. CULTURAL RESOURCES

Cultural resources include both prehistoric resources commonly associated with archeological sites and with historic resources associated with land marks. The Mammoth Cave area has numerous archeological and historical resources (Figure I-69).

Prehistoric Resources

During prehistoric times, peoples of four Indian cultures inhabited the Mammoth Cave area. The cultures are Paleo-Indian, Archaic Indian, Woodland Indian, and Mississippian Indian. Each group is briefly described below.

Paleo Indians - Toward the end of the last Ice Age the cave country near the Green River was visited occasionally by far-wandering bands of mammoth and mastodon hunters known today as Paleo Indian peoples. As the climate changed and the herds of mammoths and mastodons decreased in size, these Indians began to hunt deer and small game and to gather wild fruits, nuts and berries. This Paleo Indian period lasted until about 3000 B.C. There is little evidence that these peoples even knew of the existence of caves in the area.

Archaic Indians - Peoples of the Archaic Indian culture were more sedentary than the Paleo Indians. They lived around shell mounds that mark their camping spots. There is little evidence that they used the caves in the area except to occasionally occupy the entrance area. They probably constructed temporary lean-tos from skins and branches. Spears were used for hunting; fishhooks were used for fishing; sewing and weaving were practiced; and plants were ground with mortar and pestle. As this culture evolved, pottery in a primitive form was produced, and open fires were used for cooking. The Archaic Period lasted from about 3000 B.C. to 1000 B.C.

TABLE I-33.

RETAIL BUSINESS TRENDS (NUMBER OF ESTABLISHMENTS)

	Number of Establishments								
County	1948	% Change 1948-58	1958	% Change 1958-63	1963	% Change 1963-67	1967	% Change 1967-72	1972
BARREN	299	6.7	319	13.5	362	-6.9	337	6.2	358
EDMONSON	90	-30.0	63	15.9	73	-13.7	63	9.5	69
HART	197	-21.3	155	2.6	159	9.4	174	-11.5	154
TOTALS	586	-8.4	537	10.6	594	-3.4	574	1.2	581

Sources: Retail Trade Area Statistics, U.S. Census of Business, 1948, 1958, 1963, 1967 and 1972.
BRADD 1978 Data Book.

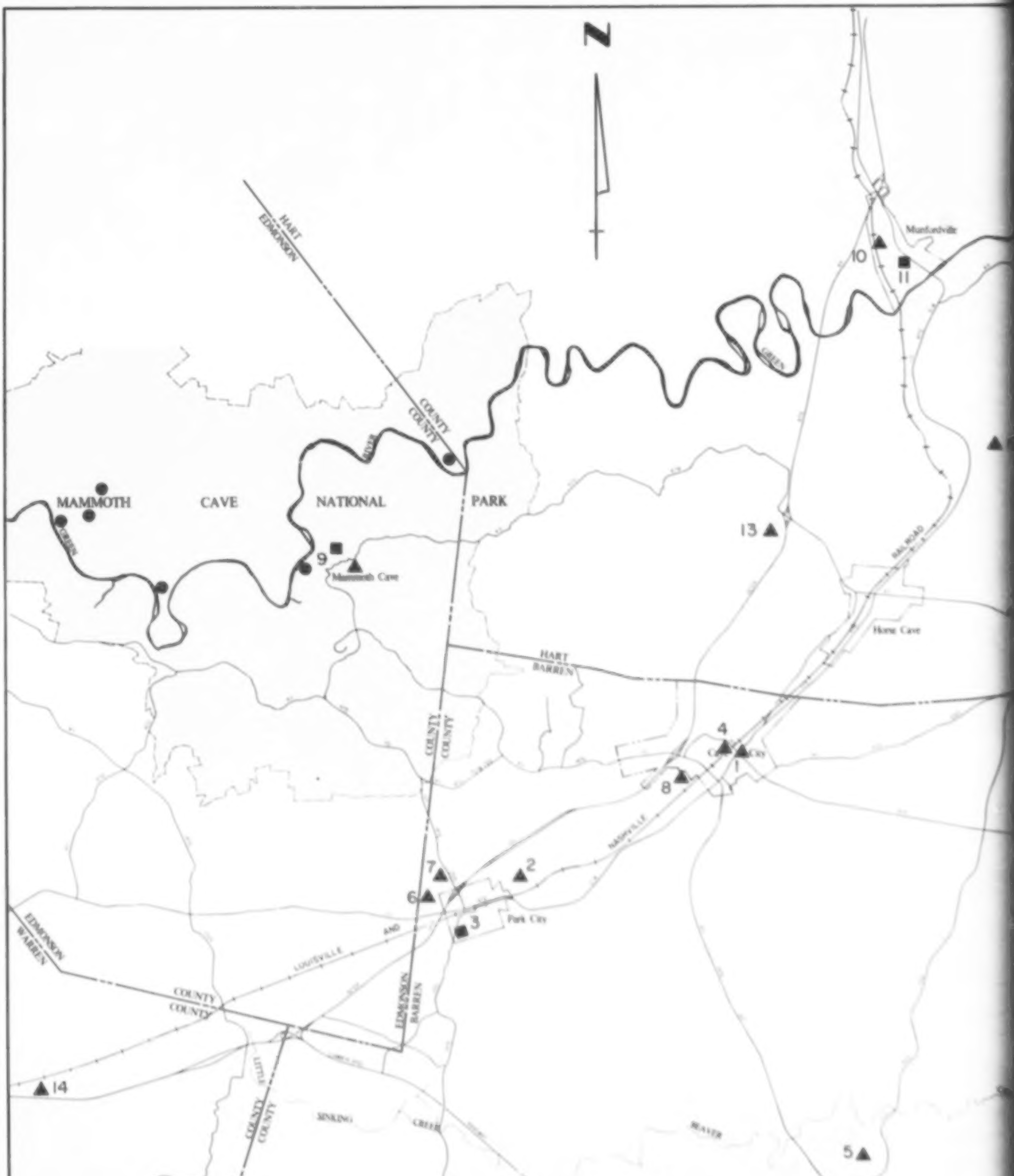
TABLE I-34.

RETAIL BUSINESS TRENDS (SALES)

	Sales (In Thousands of Dollars)						
County	1948	% Change 1948-58	1958	% Change 1958-63	1963	% Change 1963-67	1967
BARREN	17,098	61.1	27,540	22.8	33,819	18.1	39,948
EDMONSON	1,656	46.1	2,419	57.6	3,812	- 2.6	3,714
HART	6,252	66.0	10,378	14.6	11,889	13.1	13,448
TOTALS	25,006	61.3	40,337	22.8	49,520	15.2	57,110

Sources: Retail Trade Area Statistics, U.S. Census of Business, 1948, 1958, 1963 and 1967.

BRADD 1978 Data Book.


N
HART
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Mammoth Cave
Munfordville
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RAILROAD
Horse Cave
HART
BARREN
COUNTY
COUNTY
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Cave City
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NASHVILLE
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Park City
EDMONSON
WARREN
LOUISVILLE
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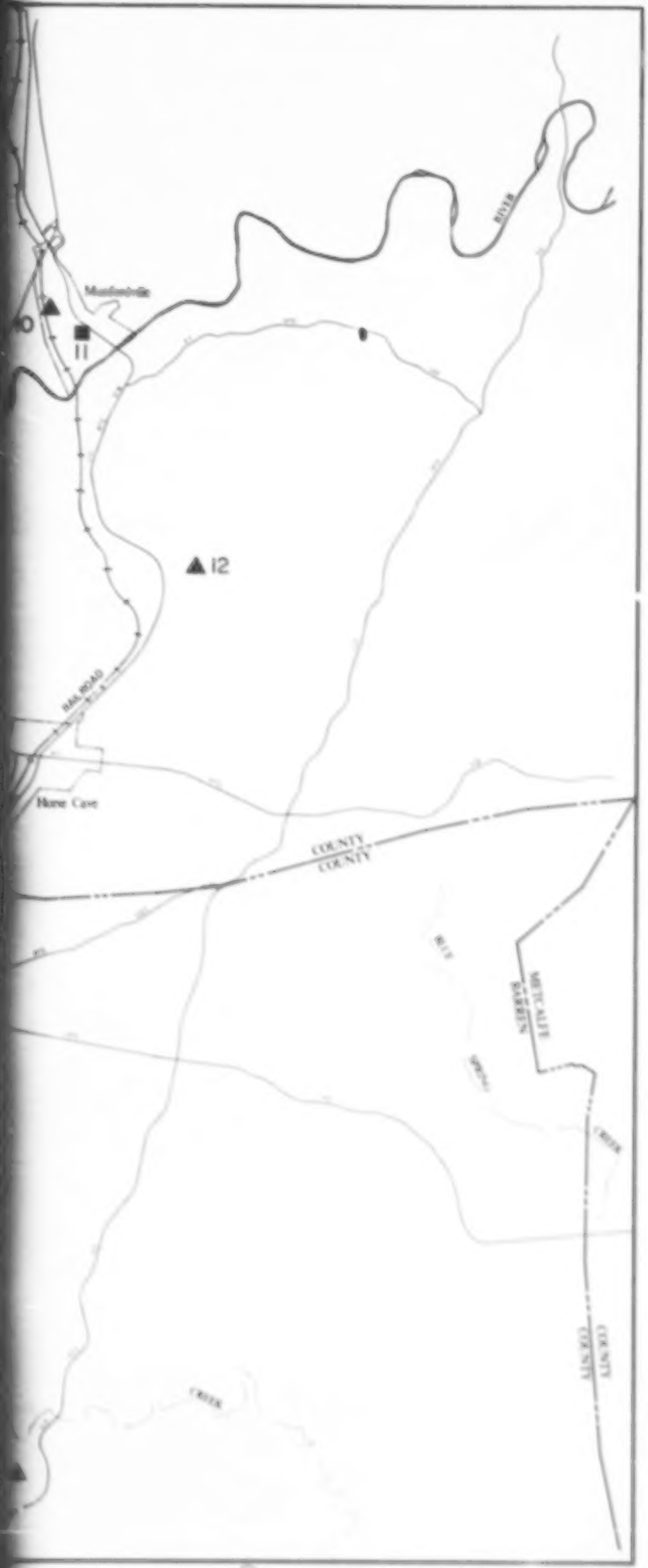

RIVER
Munfordville
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RAILROAD
Horse Cave
COUNTY
COUNTY
BLUE
SPRING
METCALFE
BARREN
CREEK
COUNTY
COUNTY
CREEK

LEGEND

▭ MAMMOTH CAVE NATIONAL PARK

● ARCHEOLOGICAL SITES

■ HISTORICAL SITES

▲ RECREATIONAL SITES

NOTE: NUMBERS CORRESPOND TO NUMBERS LISTED ON TABLE II-29

FIGURE I-69

MAMMOTH CAVE AREA
201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

ARCHEOLOGICAL, HISTORICAL AND RECREATIONAL SITES

12,000 6000 0 12,000 24,000
Scale in Feet

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia

B

Woodland Indians - As agriculture and pottery became more common and important, a new culture evolved. The Woodland Indians, whose culture thrived from 1000 B.C. to 400 A.D., farmed actively by clearing brush, weeding and planting. Berries, fruits and nuts were collected in baskets of split cane and twine. Dogs were the only domestic animals, so hunting and fishing were common. Weaving of a coarse bark fiber was developed. The caves were used at times for shelter and for storage. Gypsum was collected as deep as 2 miles inside Mammoth Cave. The use of this gypsum is not known.

From 800 B.C. the culture had advanced so much in this area that it has been referred to as the Adena culture. The Adena people, unlike the other Woodland Indians, were divided into commoners and individuals of special position. Great tombs and elaborate burials were provided for these men when they died. The area around Mammoth Cave served as a starting point for these early farmers. In time, they began to move away, and by 400 A.D. the cave region was abandoned.

Mississippi Indians - The Mississippian Indian culture developed in the west, outside of the Mammoth Cave area. These Indians did eventually move into the area around 900 A.D. They were farmers of corn, beans and squash. Because the area was not flat enough for the farming techniques of this culture, the cave region was primarily used for hunting. The caves were probably visited and slightly explored, but they were not used by these peoples for anything.

Development of Mammoth Cave Area

During the last twenty-five years of the 1700's, the Green River Valley was populated by hunters, travelers and settlers. The earliest specific reference to ownership of the caves and area is a certificate dated in 1798 and issued to Valentine Simmons. The War of 1812 brought nationwide interest to Mammoth Cave because of the salt petre deposits that were used in the making of gun powder. The Cave ownership changed hands several times throughout the period of the war. From 1816 onward, Mammoth Cave was visited by tourists. During pre-Civil War days, visitation to the cave was from 30,000 to 40,000 persons annually. Visitation has been increasing yearly. By an Act of Congress on May 25, 1926 Mammoth Cave became a National Park.

In 1798, Barren County became Kentucky's thirty-seventh county. Glasgow is the county seat and Cave City is the second largest town.

Hart County became the sixty-first county in Kentucky in 1819. Munfordville, the county seat, grew up around Munford Inn, a famous stopping place since 1806 for travelers. During the Civil War, Munfordville was the site of a Union fort which was taken by General Bragg.

Historical Resources

In Mammoth Cave National Park there are numerous historic sites. The entrance that led to the discovery of the cave is known as the Historic Entrance. Inside the cave are relics from salt petre mining operations. There are remains of huts from Dr. John Croghan's unsuccessful hospital for tuberculosis patients. The hotel, although remodeled, is of historical interest. The casket and farmhouse of Floyd Collins, discoverer and explorer of caves in the area, can be seen near Crystal Cave in Mammoth Park. A replica of Hercules and Coach No. 2, the locomotive that took visitors from Glasgow Junction (now Park City) to Mammoth Cave from 1886-1931, is on display in the park. This has been placed on the 1978 National Register of Historic Places, Department of Interior. Of historic interest are three one-room frame churches; Good Spring Church, Jappa Church, and Mammoth Cave Church.

Outside of the park, Bell's Tavern in Park and Old Munford Inn in Munfordville, are historic sites where travelers used to spend the night when traveling through the area.

Sources:

Douglas W. Schwartz. 1965. Prehistoric Man in Mammoth Cave

Burton Faust. 1967. Salt-petre Mining in Mammoth Cave, Ky.

Margaret M. Birdwell. 1952. The Story of Mammoth Cave National Park, Kentucky

Industrial Resources, Horse Cave & Munfordville, Kentucky, Kentucky Dept. of Commerce

Industrial Resources, Cave City, Kentucky, Kentucky Dept. of Commerce

Final Environmental Statement, Mammoth Cave National Park, Dept. of the Interior

National Register of Historic Places. Dept. of Interior. February 1978.

5. RECREATIONAL RESOURCES

Table I-35 presents the private, city, county, and federally owned recreation areas in the study area. These recreational areas are mapped on Figure I-69.

Mammoth Cave National Park is the most important recreational resource in this area. The park is located primarily in Edmonson County with small portions in Barren and Hart Counties. Within the park are the most extensive caverns and some of the finest examples of karst topography in the world, abundant wildlife, and artifacts of ancient people. The park offers the following variety of activities that vary in number and type throughout the season:

1) The Visitor's Center

2) Cave trips - A variety of tours lasting from 1 ½ hours to 6 hours are offered. Tours for wheelchair patients are also available.

3) Nature trails - Guided and self-guided, hiking or driving tours are available.

4) Scenic boat tours on the Green River.

5) Camping and picnicking facilities.

6) Dining and lodging facilities

Because the towns are small, the area is primarily rural, and Mammoth Cave National Park, Barren River State Park and Nolin River Lake are close to the towns, there are not a lot of parks in the study area. Most of the campgrounds cater to tourists and are privately owned. Cave City, Park City and Munfordville have city parks that are in need of expansion of facilities. Area schools also provide playground facilities for area residents. Horse Cave, Cave City and Park City are each in need of an additional small park that provides benches and playground facilities for children.

The area has potential for increased recreational facilities. There are many caves on private property that would provide spelunkers with a variety of caves ranging from easily explored to challenging. The large amounts and marginal agricultural land and forested areas could be used for campgrounds. Fishing and swimming are limited because of the scarcity of surface water in the area.

Discussion of the usage of recreational facilities in the area will be limited to use of the National Park. A large percent of the Park's visitors originate within Kentucky and the four heavily industrialized states to the north. The numbers of visitors to both the park and the caves have been increasing:

Year	Number of Cave Visitors	Number of Park Visitors
1952	217,015	400,000
1962	284,025	569,319
1972	661,136	1,872,870
1973	679,000	1,927,000
1975	650,000	2,000,000

Source: An Open Space and Recreation Plan, BRADD Mammoth Cave, the Great Onyx Job Corps Civilian Conservation Center, Environmental Assessment, November 1976.

6. TRANSPORTATION

Of the major components of the transportation system, highway, air, rail and water, only the highway and rail systems have any significant impact in the study area. There are no navigable waters in the study area. In addition, the nearest air service is limited and located in Bowling Green, Kentucky about 22 miles south of Park City.

Highways

Three Federally numbered highways serve the study area, I-65, US 31-W and US 31-E. Important State numbered highways serving the area include the Cumberland Parkway and Kentucky routes 70, 90 and 255.

Interstate 65 - This four lane federal aid route traverses through the middle of the study area and serves as a major link between Chicago to the North and Mobile, Alabama to the south. There are interchanges at each municipality in the study area. The route is the major factor in the increase of tourism in the area since it provides easy access to the Mammoth Cave National Park and environs from such large population centers as Nashville, Tennessee, Louisville, Kentucky, Cincinnati, Ohio and Indianapolis, Indiana.

US 31-E - This route lies in the western part of the study area and parallels I-65.

US 31-W - This route was replaced by I-65 and also serves as the local connection for the four municipalities in the study area. The highway still carries a substantial volume of tourist traffic.

Cumberland Parkway - This is a major four lane toll road which connects the area with eastern Kentucky. The route passes through the southern postion of the study area and joins I-65 about 10 miles south of Park City.

Kentucky 70 - This east-west route passes through the center of the study area and serves as the major highway in the southern portion of Mammoth Cave National Park.

Kentucky 90 - This route enters the study from the south and connects Cave City and Glasgow, Kentucky.

Kentucky 255 - This highway enters the study area from the south, passes through Park City and continues to the National Park Boundary. The route presently serves as the major access to Mammoth Cave National Park. The section between Park City and Chaumont is expected to become of even greater importance with the implementation of the National Park Master Plan, since the plan calls for a staging area to provide visitor access to the park to be located just inside the park entrance at Chaumont.

Bus Service - There are at present no mass transit systems in the planning area: however, the Mammoth Cave National Park Master Plan calls for providing "a public transit system that will eliminate congestion created by privately operated vehicles and that will supply efficient comfortable transportation for park visitors". Interstate bus service is available at each of the municipalities with north-south I-65 connections provided by Greyhound.

Railroads

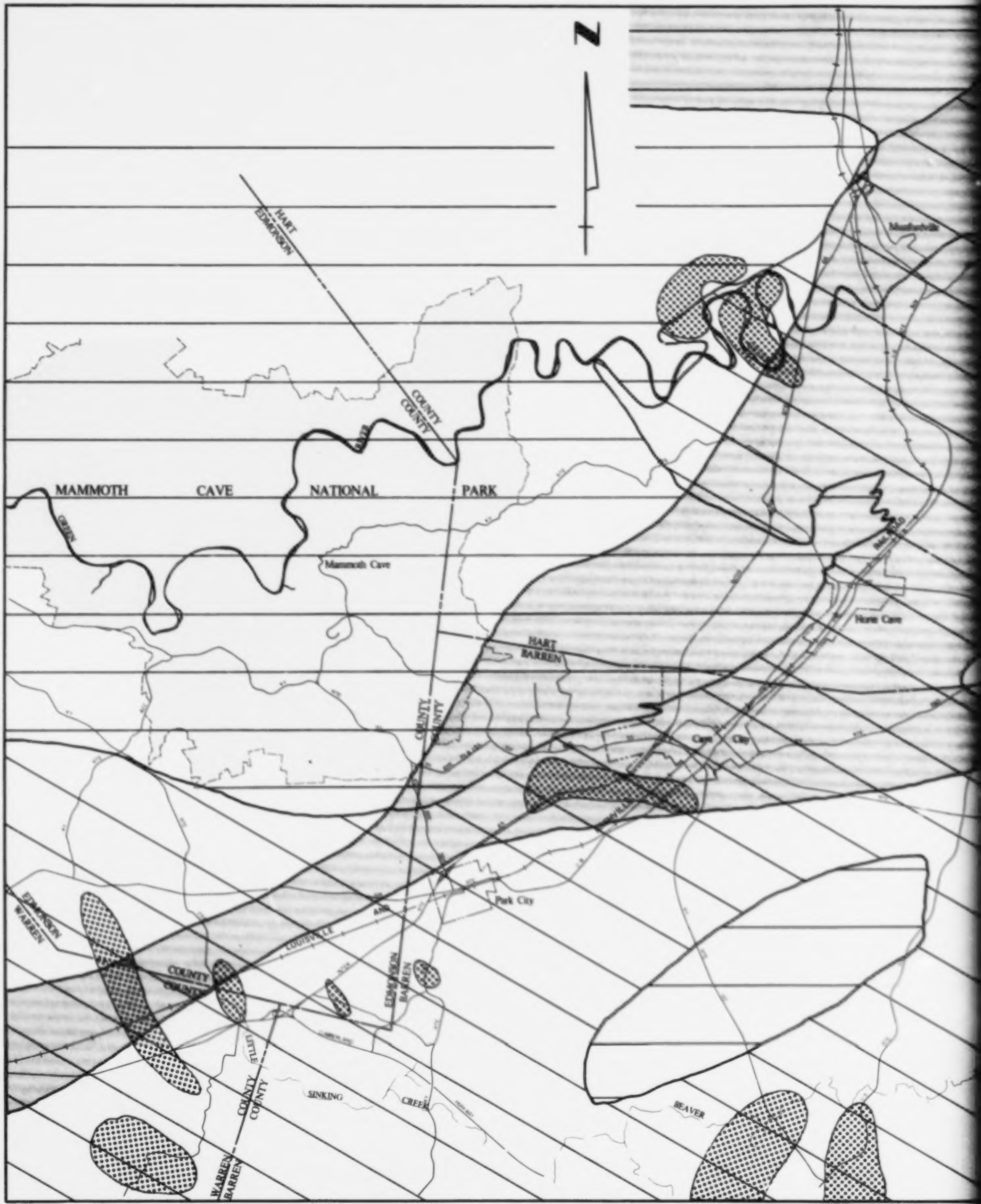
Freight - The L&N railroad parallels I-65 and provides daily freight service to Horse Cave, Munfordville and Cave City. Freight stops are also made in Park City.

Passenger Service - The nearest passenger service is located in Bowling Green, Kentucky, south of the study area. Amtrak provides one run north and one run south each day.

7. RESOURCE USE

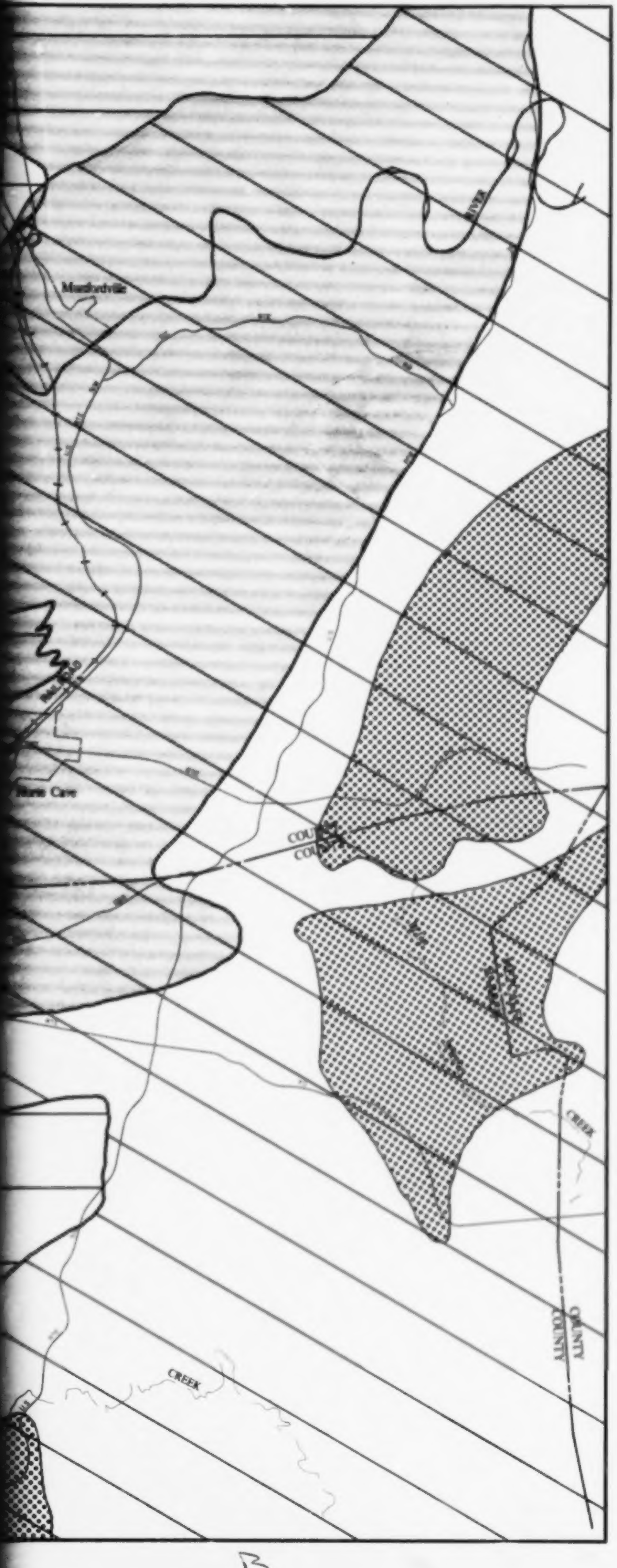
Most of the area is in agricultural and silvicultural use (Table I-36 and Figure I-70). Agricultural lands are used for both crops and pasture. Corn for grain, soybeans, clover and hay are grown. Marginal croplands are used for pasturing primarily hogs and cattle.

The forested areas are primarily eastern red cedar, scrub oak and hickory hardwood, some of which are used for timber. The forested areas in the Mammoth Cave National Park are not cut for commercial purposes. Forest lands are increasing slightly as marginal agricultural lands are stocked with trees. The


N
HART
EDMONSON
COUNTY
COUNTY
GREEN
RIVER
MAMMOTH
CAVE
NATIONAL
PARK
Mammoth Cave
Munfordville
Horse Cave
HART
BARREN
COUNTY
COUNTY
Cave City
Park City
EDMONSON
WARREN
COUNTY
COUNTY
LOUISVILLE
AND
EDMONSON
BARREN
LITTLE
SINKING
CREEK
BEAVER
WARREN
BARREN
COUNTY
COUNTY

A

I-131


RIVER
Munfordville
Horse Cave
COUNTY
COUNTY
CREEK
CREEK
COUNTY
COUNTY

B

LEGEND

- ▭ MAMMOTH CAVE NATIONAL PARK
- ▭ HIGH CALCIUM - LIMESTONE
- ☰ SILVICULTURE
- ▧ AGRICULTURE
- ▩ OIL AND/OR NATURAL GAS

FIGURE I-70

MAMMOTH CAVE AREA
201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

NATURAL RESOURCES

12,000 6000 0 12,000 24,000
Scale In Feet

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia

percent commercial forest of total land area in each county is shown in Table I-37. The portion of Warren County in the study area is primarily agricultural land.

A section of the study area contains high calcium limestone reserves that are not heavily mined. There are no strip mines or coal reserves in the area.

Oil and natural gas resources within the study area are located around and north of Glasgow, the eastern tip of Warren County, west of Munfordville, near Cave City, east of Hiseville, and in northeastern Barren County and southeastern Hart County (Figure I-70). Petroleum and natural gas production is not high (Table I-38). The continued production of petroleum in this area is due to the fact that foreign supplies of crude oil have recently been difficult to obtain.

Sources: The River Basin Water Quality Management Plan for Kentucky. Vol. 3
Green River Basin Oil and Gas Map of Kentucky. Sheets 2 and 3.
Kentucky Geological Survey. 1971.

8. WASTEWATER PROGRAMS AND SPECIAL PROBLEMS

Wastewater Programs

The proper treatment and disposal of wastewater in the Mammoth Cave area is the central issue of this environmental impact statement. In the study area there are five major population centers, the municipalities of Munfordville, Park City, Cave City and Horse Cave, as well as Mammoth Cave National Park (including the Great Onyx Job Corps Center). With the exception of Park City, these all maintain and operate wastewater treatment and disposal facilities. Besides these public facilities, there are non-municipal wastewater treatment plants scattered throughout the study area. In addition, sub-surface on-lot treatment and disposal (including direct discharge to sinkholes) is used extensively by individuals and commercial establishments in all areas not served by municipal sewerage facilities, including Park City. The purpose of this section is to identify existing wastewater treatment and disposal methods used in the study area as well as inventory all municipal and non-municipal wastewater treatment facilities.

Horse Cave Wastewater Facilities

The Horse Cave wastewater treatment facility is a high-rate trickling filter plant designed for a hydraulic loading of 0.4 mgd and a (BOD_5) loading of approximately 870 lbs/day. The treatment plant should be capable of providing secondary treatment. Major wastewater treatment processes include grit removal, comminution, primary sedimentation, trickling filtration, secondary sedimentation and chlorination (Figure I-71).

The treated effluent is discharged to the subsurface where it flows to the South Branch of Hidden River Cave. Sludge is treated in anaerobic digesters and dewatered with drying beds. Because of the metals contents in the sludge, disposal is prohibited in conventional landfills. Dried sludge is presently being stored at the plant site. Plant personnel are awaiting instruction from the Kentucky Division of Hazardous Material and Waste Management for proper disposal.

TABLE I-37.

PRECENT OF COUNTY LAND AREA USED AS COMMERCIAL FOREST LAND. (1966)

County	Percent
Barren	7.0
Edmonson	39.0
Hart	43.1
Warren	25.8

Source: The River Basin Water Quality Management Plan for Kentucky. Vol. 3. Green River Basin.

TABLE I-38.

ANNUAL TOTAL OIL PRODUCTION IN THE STUDY AREA
TOTAL ANNUAL OIL PRODUCTION (x 1000 GALLONS) YEAR

County	1971	1973	1975	1977
Barren	1,234	932	744	719
Edmondson	51	77	51	59
Hart	1,545	890	1,581	1,525
Warren	2,238	2,237	1,664	4,246
Total	5,068	4,136	3,040	6,549

Source: Kentucky Geological Survey, Louis R. Ponsetta, Head, Oil and Gas Section

SCHEMATIC OF HORSE CAVE WASTEWATER TREATMENT PLANT

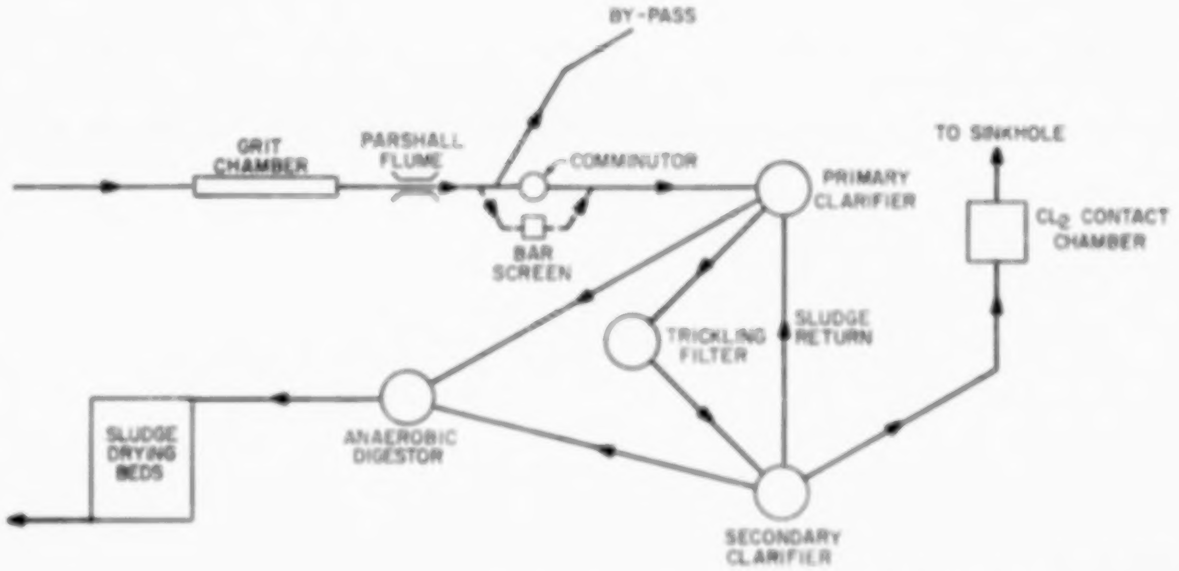

BY-PASS
GRIT CHAMBER
PARSHALL FLUME
COMMINUTOR
BAR SCREEN
PRIMARY CLARIFIER
TO SINKHOLE
Cl_2 CONTACT CHAMBER
TRICKLING FILTER
SLUDGE RETURN
SLUDGE DRYING BEDS
ANAEROBIC DIGESTOR
SECONDARY CLARIFIER

FIGURE I-7

The Horse Cave wastewater collection and treatment system serves about 90 percent of the water customers within the city's corporate limits. This includes two industrial customers, the Hart County Creamery and Ken-Dec, Inc. Also, an intercepter to serve the commercial establishments at the Horse Cave I-65 interchange was recently constructed. At this time, however, only the Rodeway Inn is discharging wastewater to the system.

The treatment plant is located just west of U.S. 31 W, about one mile south of the intersection of U.S. 31 W and Rt. 218 (Figure I-72). There appears to be sufficient area available for plant expansion.

Although Horse Cave has submitted an application, an NPDES discharge permit has not been issued for the Horse Cave wastewater treatment plant. Plant operations continue under the direction of a qualified operator with Class II certification.

Plant Performance. No effort has been made to establish a regular monitoring program at the plant. Plant performance data are therefore, very limited. However, results of sampling performed at different times during the past three years provide some information, as illustrated in Table I-39. From the results indicated in Table I-39, it is evident that performance of Horse Cave treatment plant is unsatisfactory. For example, the latest composite sample collected in August 1977 shows less than 40% BOD_5 removal.

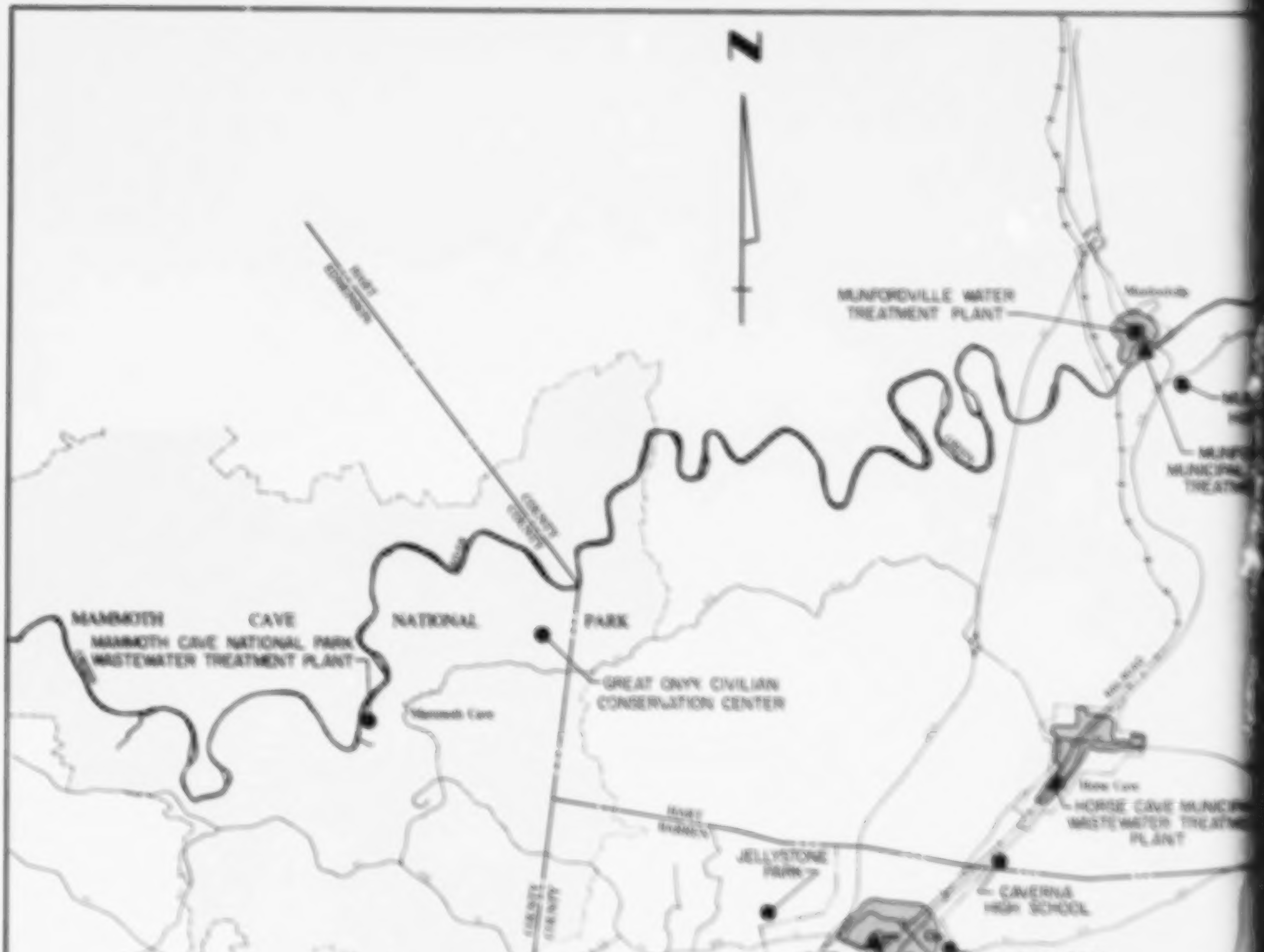
Poor plant performance is primarily due to the industrial wastewaters discharged to the plant. Influent wastewater at the Horse Cave treatment facility is not characteristic of domestic sewage. Of the estimated daily average flow of 0.37-0.39 mgd slightly over 50% is untreated industrial wastewater from the Hart County Creamery operations and Ken Dec's electroplating plant (see also Industrial Wastes inventory). The result of these industrial discharges is an influent high in BOD_5 and heavy metals concentrations. In fact, total metals in the plant influent exceed industry pretreatment standards for every sample reported. Results of grab samples (Table I-39) sited in an August 1977 sampling survey report prepared by the Kentucky Division of Water Quality indicate influent BOD_5 as high as 2,000 mg/l and concentrations of chromium (total), copper and nickel of 16.6, 48.4 and 19.8 mg/l respectively. Although these concentrations do not occur continuously, they further serve to indicate the industrial nature of the influent wastewater. Furthermore, shock loads of these concentrations of heavy metals are considered to be toxic to biological wastewater treatment processes. Visual inspection of the facility (in September 1977 and March 1978) revealed that there is little biological growth on the trickling filter media and that the anaerobic digester is no longer operational, conditions apparently the result of toxic effects of chromium, copper and nickel.

Difficulties with industrial wastes have been recognized for several years. In October 1976, the following recommendations regarding the plant were made by Mr. Clyde P. Baldwin of the Kentucky Division of Water Quality:

"1) The City of Horse Cave must institute and enforce a strong sewer use ordinance;

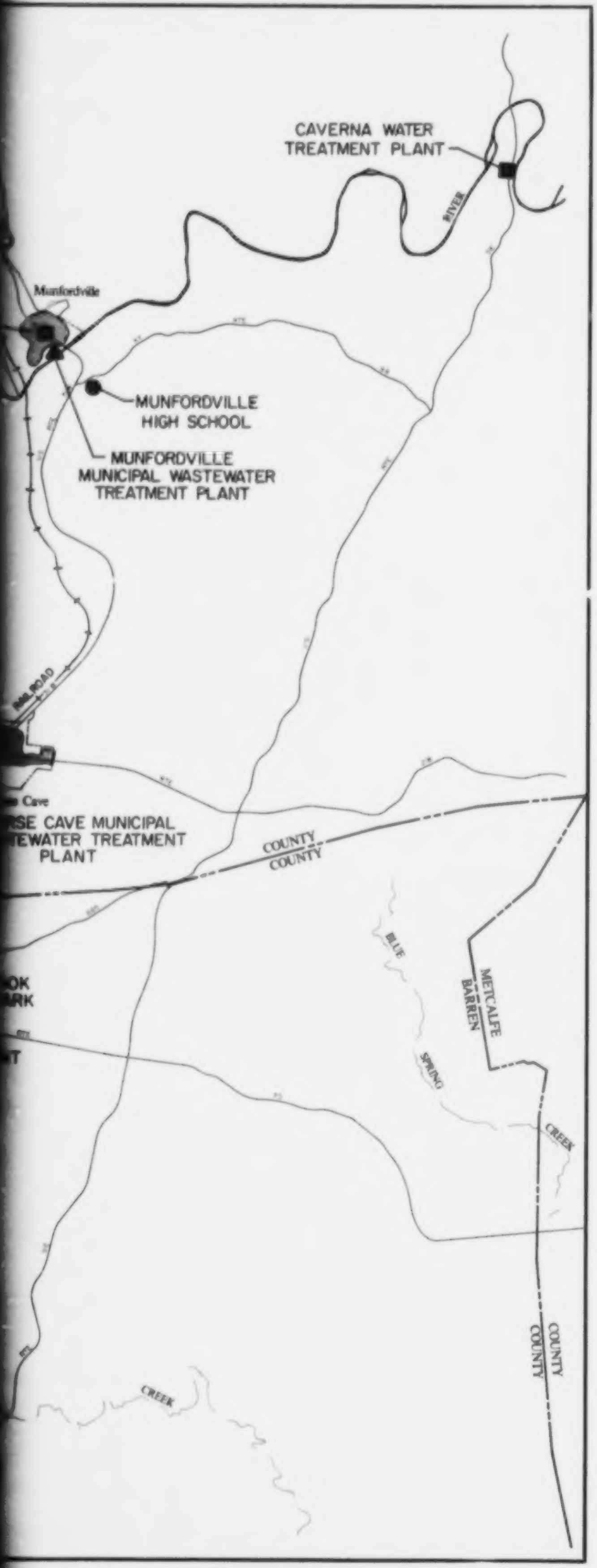
2) The City of Horse Cave reduce the heavy metal limits by 2/3 their present agreement with Ken Dec;

3) The Horse Cave sewage treatment plant digester be completely emptied and the sludge placed at a location approved by the Division of Water Quality;


N
MUNFORDVILLE WATER TREATMENT PLANT
Munfordville
MUNICIPAL
TREATMEN
GREEN
MAMMOTH CAVE NATIONAL PARK
MAMMOTH CAVE NATIONAL PARK WASTEWATER TREATMENT PLANT
Mammoth Cave
GREAT ONYX CIVILIAN CONSERVATION CENTER
HART
EDMONSON
COUNTY
COUNTY
Horse Cave
HORSE CAVE MUNICIP
WASTEWATER TREATM
PLANT
HART
BARREN
JELLYSTONE PARK
CAVERNA HIGH SCHOOL
SUNNYBROOK TRAILER PARK
CAVE CITY MUNICIPAL WASTEWATER TREATMENT PLANT
CRYSTAL ONYX CAVE
PARK CITY CAMPGROUND
KOA CAMPGROUND
PARK MAMMOTH RESORT
Park City
SOUTHERN STATES FEED MILL
PARK CITY SCHOOL
EDMONSON
WARREN
LOUISVILLE AND
COUNTY
COUNTY
EDMONSON
BARREN
BOW AIR TOLL PLAZA
SINKING
CREEK
WARREN
BARREN
COUNTY
COUNTY
BEAVER

A

I-135.a


CAVERNA WATER TREATMENT PLANT
RIVER
Munfordville
MUNFORDVILLE HIGH SCHOOL
MUNFORDVILLE MUNICIPAL WASTEWATER TREATMENT PLANT
RAILROAD
Cave
RSE CAVE MUNICIPAL
TEWATER TREATMENT
PLANT
COUNTY
COUNTY
OOK
ARK
NT
BLUE
SPRING
CREEK
METCALFE
BARREN
COUNTY
COUNTY
CREEK

LEGEND

☐	MAMMOTH CAVE NATIONAL PARK
▨	MUNICIPAL SEWERAGE SERVICE AREAS
●	NON-MUNICIPAL
▲	MUNICIPAL
■	WATER TREATMENT FILTER BACKWASH SEDIMENTATION

FIGURE I-72

MAMMOTH CAVE AREA
201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

WASTEWATER TREATMENT FACILITIES

12,000 6000 0 12,000 24,000
Scale In Feet

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia

B

TABLE I-39

HORSE CAVE WASTEWATER TREATMENT PLANT

PERFORMANCE DATA

Date of Sample	Sample Collection	Type of Sample	Source	BOD_5	SS	NH_3-N	pH	Cu	Cr^{+6}	Cr_T	Ni	Zn	Total Metals (Cr+Zn+Cu+Ni)	Cd	Pb	Fe
10/22/75 (7:30 a.m.)	Kentucky Div. of W.Q.	Grab	Influent	945	360		5.7	2.72		1.19	2.58	6.2	12.7	.005	.038	.434
10/22/75 (7:30 a.m.)	Kentucky Div. of W.Q.	Grab	Effluent	144	50		6.8	1.6		3.62	1.98	8.82	16.	.003	.028	.322
11/12/75 (10:30 a.m.)	Kentucky Div. of W.Q.	Grab	Influent	987	233											
11/12/75 (10:30 a.m.)	Kentucky Div. of W.Q.	Grab	Effluent	124	43											
12/4/75 (9:00 a.m.)	Kentucky Div. of W.Q.	Grab	Influent	148	48											
12/4/75 (9:00 a.m.)	Kentucky Div. of W.Q.	Grab	Effluent	106	32											
5/20/75	Kenvirons, Inc.	Composite	Influent	1081	340	20	7.2	.732		2.26	4.14	1.1	8.2	.047	.078	1.36
5/20/75	Kenvirons, Inc.	Composite	Effluent	405	153	12	6.9	.458		1.34	2.08	.552	4.43	.05	.034	.596
6/9/76	Kenvirons, Inc.	Composite	Influent	320	158	16.4	7.55	2.99		.932	1.48	1.06	6.46	.002	.046	1.05
6/9/76	Kenvirons, Inc.	Composite	Effluent	261	87	13.2	7.3	2.32		.333	.932	.576	4.16	.003	<.005	.566
9/4/76	T.A. Waters (operator)	Grab	Influent					5.94		130	24.6	15.8	176.3	.007	.226	1.32
9/4/76	T.A. Waters	Grab	Influent					3.2		75	10.9	9.26	98.4	.004	.082	1.14
8/23/77	Kentucky Div. of W.Q.	Composite	Influent	316	320	12		2.62		10.5	6.36	.778	20.2	.002	.046	.642
8/23/77	Kentucky Div. of W.Q.	Composite	Effluent	202	76	6.6	7.2	1.64		6.64	1.52	.252	10.5	.002	.011	.230
8/12/77	T. A. Waters	Grab	Influent					48.4		16.6	19.3	2.6	87.4	.003	.074	1.22
8/23/77	Kentucky Div. of W.Q.	Grab	Influent	159	147											
8/24/77	Kentucky Div. of W.Q.	Grab	Influent	2153	686											
3/21/78 (11:00 a.m.)	GFCC, Inc.	Grab	Influent	316	155	6.8	7.2	7.9	10.7	25.8	20.8	.92	55.4	<.005	<0.1	0.83
3/21/78 (11:00 a.m.)	GFCC, Inc.	Grab	Effluent	96	41	8.8	7.3	6.6	7.9	16.7	12.3	.584	36.2	<.005	<0.1	0.78
Pretreatment Standards for the Electroplating Industry (>10,000 gpd)	Average Daily Values for 30 Consecutive Days			-	-	-	7.5-10	2.0	.09	1.6	1.8	1.5	3.9	0.5	0.4	-
	Maximum for any one (1) day			-	-	-	10	4.6	.25	4.2	3.6	3.4	7.5	1.0	0.8	-
Typical Values for Municipal High-Rate Trickling Filter Plant			Influent	200	200	25	6-9									
			Effluent	30	30	18	6-9									

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best available copy.

4) The trickling filter media be cleared of the toxic compounds or replaced;

5) The waste from the Hart County Creamery be repiped to one central point before going to the city sewers, a flow measuring and sampling device be installed at a suitable point, and the creamery's load be evaluated in detail."

With the exception of recommendation #2, these are still applicable today.

It is evident that the Horse Cave treatment plant cannot provide secondary treatment under these existing conditions. Improved operations are expected with the installation of pre-treatment facilities at the Ken Dec electroplating plant which should reduce heavy metals concentrations to levels acceptable to permit biological treatment activities. However, present BOD_5 loading already exceeds design capacity. Unless pre-treatment of the Hart County Creamery's wastewater is provided to reduce influent BOD_5, the Horse Cave treatment plant cannot be expected to produce the secondary treatment effluent for which it is designed.

Munfordville Wastewater Facilities

The Munfordville Wastewater treatment plant is a 0.15 mgd extended aeration facility which discharges to the Green River about 200 feet downstream from the Highway 31 W bridge in Munfordville, Kentucky (Figure I-72). Major plant equipment includes a bar screen, comminutor, grit chambers, Parshall flume with continuous flow measuring device, dual aeration basins and secondary clarifiers (Figure I-73). In addition, the plant has a by-pass line following the influent flow measuring device.

The Munfordville Municipal Sewerage system serves about 250 customers in the central part of the community. This represents approximately fifty per cent of the population according to the Hart County Health Department. There is also one industrial customer, a small slaughter house. Its untreated discharge does not appear to affect the plant. The collection system consists of 6 in. and 10 in. sewers and includes two lift stations and force mains to serve low-lying areas of the community. The plant is operated under NPDES permit #KY0031755 by a qualified operator with a Class II sewer certification.

Operational records for the Munfordville plant are not extensive. Latest NPDES self-monitoring data and Kentucky Compliance Monitoring Analyses indicate that the plant is performing well, providing BOD_5 reductions of about 95% and suspended solids reductions of about 90% (Table I-40). Because there are no disinfection facilities, however, the plant effluent is in constant violation of NPDES fecal coliform limits.

The August, 1977 Compliance Monitoring Survey of Munfordville, Kentucky sewage treatment facility reported that the continuous flow-measuring equipment was not usable due to problems with the float sensors. Although this equipment does not affect plant performance, continuous flow monitoring is required by Kentucky law.

SCHEMATIC DIAGRAM OF MUNFORDVILLE WASTEWATER TREATMENT PLANT

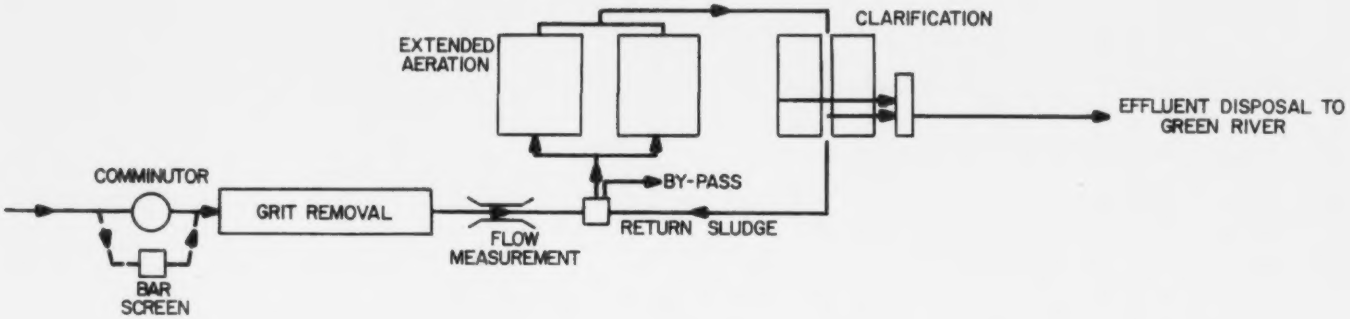
COMMINUTOR
BAR SCREEN
GRIT REMOVAL
FLOW MEASUREMENT
EXTENDED AERATION
BY-PASS
RETURN SLUDGE
CLARIFICATION
EFFLUENT DISPOSAL TO GREEN RIVER

FIGURE I-73

Since the Munfordville plant is an extended aeration facility which is loaded at about 50% design capacity, little or no waste sludge is produced. As the plant reaches design capacities, the plan is to pump sludge from the secondary clarifier with a septic-tank truck and dispose by land spreading.

Although the Munfordville plant is producing a high-quality effluent with respect to BOD_5, there are some improvements that are immediately required to meet Federal and State regulations. Continuous flow monitoring should be provided and disinfection facilities installed. In addition, some post aeration appears to be necessary to meet NPDES dissolved oxygen requirements. By making these improvements, the Munfordville plant is expected to provide satisfactory treatment to maintain water quality in the Green River.

Plant performance and flow monitoring data provided by the Kentucky Division of Water Quality indicate that there is capacity to expand the present sewerage service area. However, flows should be carefully monitored during wet-weather periods to confirm this conclusion and to determine the amount, if any, of additional capacity.

Cave City Wastewater Facilities

The Cave City treatment plant provides biological wastewater treatment by means of a high-rate trickling filter with a design capacity of 0.32 mgd. Other plant processes include grit removal, comminution, primary and secondary sedimentation, sludge digestion and chlorination (Figure I-74). Continuous effluent flow-monitoring is provided. Sludge is dewatered on drying beds. The dry sludge is stored in large piles nearby and occasionally used for land application by local farmers. Treated effluent is discharged to a sinkhole, together with siltrate from the sludge drying beds, and flows to the East Branch of Hidden River Cave according to results of recent dye tracing work performed by J. Quinlan (personal communication).

The Cave City sewerage system is maintained within the corporate limits of Cave City and serves about 600 customers (about 90% of the population) including commercial establishments. The collection system consists of 8-inch sewers with some 10-inch trunk lines carrying sewage to the treatment plant. Three pumping stations are used to lift wastewater from low areas to gravity sewers. The wastewater treatment plant is located near the L&N Railroad tracks (Figure I-72) and is surrounded by open fields. There appears to be ample space at the site for expanding and upgrading the treatment facilities.

Both NPDES self-monitoring data and compliance monitoring by the Kentucky Division of Water Quality indicate that the Cave City treatment plant is not providing the level of treatment required by NPDES permit KY0025763 (Table I-41). Even with ideal operating conditions, however, the treatment facility cannot be expected to meet these stringent discharge limits since the high-rate trickling filter is designed to provide only secondary treatment (85% BOD_5 removal).

Plant performance should be judged according to the plant's secondary treatment design criteria. Again, inspection of Table I-41 indicates that plant performance is not satisfactory. During the summer months, when efficiency should be at a peak, plant BOD_5 removals are only about 76% even when loaded below design capacity. Plant operation improvements are apparently necessary to maintain secondary treatment levels. However, significant process changes

SCHEMATIC DIAGRAM OF CAVE CITY WASTEWATER TREATMENT PLANT

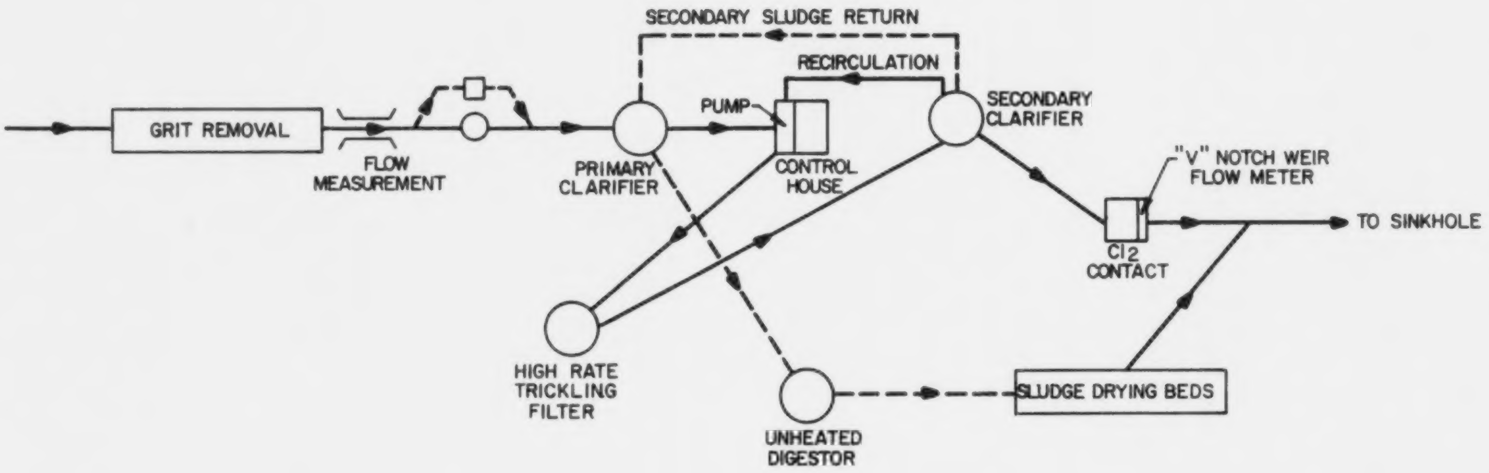
GRIT REMOVAL
FLOW MEASUREMENT
PRIMARY CLARIFIER
SECONDARY SLUDGE RETURN
RECIRCULATION
PUMP
CONTROL HOUSE
SECONDARY CLARIFIER
"V" NOTCH WEIR FLOW METER
Cl2 CONTACT
TO SINKHOLE
HIGH RATE TRICKLING FILTER
UNHEATED DIGESTOR
SLUDGE DRYING BEDS

FIGURE I-74

are required to meet NPDES permit conditions. The effects of these NPDES effluent limits on groundwater quality will be assessed in the groundwater studies portion of the EIS.

According to 1977 plant flow records, the highest wastewater flows occurred in July and August, the peak of the tourist season. The average daily flow recorded during these months was 0.252 mgd. However, a compliance monitoring report performed by the Kentucky Division of Water Quality on August 23-24, 1977 indicates the plant's flow recorder to be reading 14% too high. Therefore, actual daily average flow for the months of July and August is estimated to be about 0.22 mgd, approximately 0.1 mgd less than the plant's design capacity of 0.32 mgd. Since the BOD_5 concentration in the influent is typical for domestic wastewaters, it is expected that additional wastewaters (up to .32 mgd) may be treated without adversely affecting the plant's ability to provide secondary treatment.

Mammoth Cave National Park Wastewater Facilities

Wastewater generated in the National Park at the Historic Entrance area, comfort station in Great Relief Hall of Mammoth Cave, and park residence and utility area is collected and treated at the park's wastewater treatment plant, located near the Green River (Figure I-72). The facility is a high-rate trickling filter plant with a design capacity of 120,000 gpd. Major plant units include an Imhoff tank (primary sedimentation and anaerobic sludge digestion), dual trickling filters, secondary clarifiers, chlorine contact chamber and sludge drying beds (Figure I-75). Treated effluent is discharged to the Green River, while dried sludge is trucked to a local sanitary landfill in Edmonson County.

Visual inspection of the plant during the preparation of this report revealed that the plant is well operated and maintained. This observation is confirmed by plant operation data from the past year which indicate the plant to be consistently providing secondary (or better) treatment in compliance with NPDES permit KY0021156 (Table I-42). There are no known water quality violations due to the plant's discharge.

During the peak tourist season (July and August), the average daily flow to the plant is reported to be 75,000-85,000 gpd. However, flow records indicate that during the winter months, flows are extremely high. In the month of February 1978, when flow averaged 98,000 gpd a maximum day of 280,000 gallons (2.3 times design capacity) was recorded. In March, although the maximum day (207,000 gal) was less, average daily flow was determined to be 104,000. In reviewing the plant flow records, it is determined that not only are extremely high flows recorded immediately following rainfall or snow melt events, but that during periods of wet weather, flow is generally higher than even in the peak tourist season. These data indicate that an infiltration/inflow problem exists in the Mammoth Cave wastewater collection system. However, water consumption and wastewater flow data do not indicate that major sewage leakage (exfiltration) is a problem in the Mammoth Cave system.

Although daily average flow during any month does not exceed design capacity, wastewater flows during wet weather periods regularly exceed this capacity. Therefore, an investigation of the infiltration/inflow (I/I) problem is necessary to determine any limitations on future use of the wastewater treatment facility.

SCHEMATIC DIAGRAM OF MAMMOTH CAVE NATIONAL PARK WASTEWATER TREATMENT PLANT

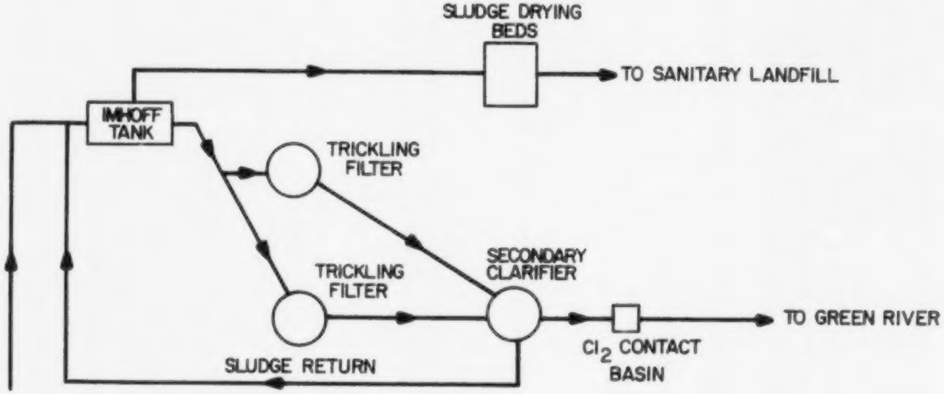
SLUDGE DRYING BEDS
TO SANITARY LANDFILL
IMHOFF TANK
TRICKLING FILTER
TRICKLING FILTER
SECONDARY CLARIFIER
TO GREEN RIVER
Cl_2 CONTACT BASIN
SLUDGE RETURN

FIGURE I-75

Since the peak tourist season does not correspond to periods of wet weather, however, I/I may not seriously affect the treatment capacity of the plant during the summer months. Assuming the I/I problem can be eliminated, there appears to be sufficient capacity to accomodate greater wastewater flows due to the increased park visitation anticipated in the Mammoth Cave National Park Master Plan. Based on these projections, the plant appears to have adequate capacity to continue to provide secondary treatment until the mid 1980's. However, if wastewater from over the proposed staging area at Chaumont is treated at a different facility, the existing plant should have adequate capacity well after 1985.

The Mammoth Cave wastewater treatment facility is presently in compliance with the NPDES permit program. It is expected that maintaining these effluent limits will protect water quality in the Green River. However, if more stringent effluent limits are required after expiration of the existing permit, upgrading of the treatment processes will be required. There is adequate space at the treatment plant site to accomodate additional treatment units.

Great Onyx Civilian Conservation Center Wastewater Treatment Plant

Wastewater generated from activities at the Job Corps' Great Onyx Civilian Conservation Center is treated in three waste stabilization lagoons. Effluent from the lagoons is chlorinated before discharge to the Green River. However, before the pipeline was added for discharge to the Green River, overflows from the lagoons drained through nearby crevices into the cave system. The design capacity of the system is approximately 20,000 gpd to provide for a population of 200 at the center.

Monitoring data indicate that the lagoon system is consistently providing secondary (or better) treatment (Table I-43), meeting the conditions of NPDES permit KY0028002.

According to the Mammoth Cave Master Plan, the Conservation Center is slated to close before the year 2000. Therefore, further consideration of wastewater treatment at the facility is considered unnecessary.

Small Wastewater Treatment Plants

There are eleven (11) small wastewater treatment plants located in the study area, most of them near the municipalities of Park City, Cave City and Munfordville. These facilities are identified in (Table I-44) and their locations indicated in Figure I-72. However, no operating data are available for any of these wastewater treatment plants since monitoring programs are not yet established.

Of these eleven plants, nine have either direct or indirect discharges to groundwater. Five discharge directly to the sub-surface via sinkholes. Four discharge to lagoons with no outlet, but the water percolates into the ground. The impacts of these facilities on groundwater quality are unknown. Because of the nature of the wastewater, the relatively small flows and because there are no known water quality problems associated with such plants, it is presently assumed that impacts are minimal. However, in generating alternative wastewater treatment systems for the area a more detailed assessment is required.

Industrial Wastewater

There are only two significant sources of industrial wastewaters in the study area, the Hart County Creameries, Inc. (cheddar cheese, cheese by-products) and Ken Dec, Inc. (electroplating). Both industries are located in Horse Cave, Kentucky, and discharge process wastewaters to the Horse Cave Municipal sewerage system. There is also a small slaughterhouse in Munfordville which discharges wastewater to the Munfordville system. However, even during peak months, daily flows average only 500 gallons per day. This represents only about 0.8% of the hydraulic loading and approximately 4% of the organic load* received by the Munfordville wastewater plant. Its impact is, therefore, considered negligible.

The adverse impacts on the Horse Cave wastewater treatment plant caused by the unpretreated discharges of the Hart County Creameries, Inc. and Ken Dec, Inc. are discussed in the Wastewater Treatment Facilities section of this chapter. The purpose of this section is to provide information regarding wastewater characteristics and flows.

Ken Dec, Inc. - During the past year water use at the Ken Dec electroplating plant increased to about 7,000,000 gallons per month for an average of about 230,000 gpd. It assumed that approximately 90% of this (207,000 gpd) is discharged as process wastewater. Water use data from June 1976 to July 1977 is presented in Table I-45. These data indicate the rise in water consumption until July 1977. In subsequent months, water use has remained near 7,000,000 gallons per month.

The most extensive data collection on Ken Dec's wastewater characteristics was performed for Ken Dec's progress reports 8-12 during the period from October 2 through December 12, 1975. Results of this sampling and analysis appear in Table I-46.

These data indicate that proposed pretreatment standards for pH, CN, Cr_t, Cr_6, Cu, Zn and total metals are exceeded for these long-term composite samples. Composite samples do not, however, reflect the extreme variation in concentration of heavy metals as indicated by grab sample data. The fluctuation in concentrations cause shock loads at the municipal wastewater treatment plant. These are considered even more detrimental to biological processes than constant exposure to high concentrations of certain metals. The results of grab samples are indicated in Table I-46.

Ken Dec, Inc. has started operations of recently installed pretreatment facilities. According to estimates prepared by the design engineer, the facilities are capable of providing effluent quality indicated in Table I-47. However, according to plant officials, initial data indicate greater performance than anticipated.

* Based on typical slaughterhouse wastewater
Eckenfelder, Water Quality Engineering, pg. 84

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TABLE I-46 WASTEWATER CHARACTERISTICS
INDUSTRIAL DISCHARGE OF KEN DEC, INC.
(Concentration-mg/1)

Proposed Pretreatment Standard		30 day ave. (mg/1) Max for any day (mg/1)		(0.24) (0.64)	(1.6) (4.2)	(.09) (.25)	-	(2.0) (4.6)	(1.8) (3.6)	(1.5) (3.4)	(3.9) (7.5)
Sample Collection	Sampling Date	Type Sample	pH	CN	CrT	Cr^{+6}	Fe	Cu	Ni	Zn	*Total Metals
Ken-Dec	9/2-9/5	4 day comp.	8.0	nil	0.85	.064	0.6	-	-	1.2	-
Ken-Dec	9/15-9/19	5 day comp.	8.3	nil	2.0	.074	.75	-	-	1.2	-
Ken-Dec	9/22-9/26	5 day comp.	8.3	nil	0.81	.020	.20	-	-	.55	-
Ken-Dec	9/29-10/3	5 day comp.	7.6	nil	3.5	.090	.57	1.8	0.23	3.9	9.4
Ken-Dec	10/6-10/10	5 day comp.	8.3	nil	5.3	.020	.64	3.7	1.2	2.1	12.
Ken-Dec	10/20-10/24	5 day comp.	8.6	0.55	0.90	.035	.73	6.5	.36	.96	8.7
Ken-Dec	10/27-10/31	5 day comp.	9.0	0.048	0.24	0.31	.17	1.6	.13	.33	2.3
Ken-Dec	11/3-11/6	4 day comp.	10.0	0.075	4.0	.054	.42	1.4	.29	.30	6.
Ken-Dec	11/10-11/14	5 day comp.	11.4	0.508	3.1	.37	1.2	1.7	1.3	.45	21.8
Ken-Dec	11/17-11/21	5 day comp.	11.5	0.16	0.43	.047	.10	.21	.44	.04	1.1
Ken-Dec	11/24-12/1	7 day comp.	9.4	0.003	1.3	.273	.20	2.1	.13	.70	4.2
Ken-Dec.	12/2-12/6	5 day comp.	9.0	0.001	0.25	.020	.16	.25	.08	.07	0.65
Ken-Dec.	12/8-12/12	5 day comp.	9.9	0.008	1.1	.235	.20	.21	.10	.10	1.5
Kentucky Div. of W.Q.	10/22 (1:15 am)	Grab	-	-	2.24	-	.374	4.84	4.78	1.16	13.
Kentucky Div. of W.Q.	11/12 (10:30 am)	Grab	-	-	0.574	-	1.19	27.5	7.10	.82	36.
Kentucky Div. of W.Q.	12/4 (9:10 am)	Grab	-	-	0.920	-	4.76	5.28	1.72	3.38	11.3
Moore & Upton	7/19/77	Grab	-	-	264	-	.39	7.1	5.85	6.7	281.65
MSDC	3/21/7? (am)	Grab	7.0	-	34.7	35.0	0.63	9.1	29.4	[illegible]	74.3

*Total Metals = Zn + Cu + Cr_t + Ni

TABLE I-47. EXPECTED MAXIMUM CONCENTRATIONS (mg/l) OF METALS IN PRETREATED WASTEWATERS FROM KEN DEC, INC.

	Flow gpm (mgd)	Cr^{+6}	Cr_t	Cu	Ni	Zn	Total CN	Free CN	Total Metals	pH
Pretreatment Facilities Design Maximum Concentration	200(.288)	.2	1	1	1	1	.64	.2	4	7.5-10
EPA Proposed Pretreatment Standards	Maximum for any 1 day	.25	4.2	4.6	3.6	3.4	.64	.2	7.5	10
	Daily Average	.09	1.6	2.0	1.8	1.5	.24	.08	3.9	7.5-10

If the new facilities operate as expected, Ken Dec's wastewater is expected to be compatible with the biological wastewater treatment processes at the Horse Cave Municipal Plant. In addition, with these concentrations, the Horse Cave treatment plant effluent is expected to be adequate to maintain Kentucky Water Quality Standards with respect to metals. Furthermore, Ken-Dec plans to reduce water consumption by 40% in the future, lessening the impact of the industrial waste on the treatment facilities.

Hart County Creameries Inc. and Wheyco Inc. - There are two manufacturing operations at Hart County Creameries. One is the production of cheddar cheese by Hart County Creameries. The other is the manufacture of animal feed supplements from whey by Wheyco Inc., a subsidiary of Hart County Creameries. Both operations are seasonal, with greatest production in the summer months. This trend is illustrated in Figure I-76 which indicates daily average water consumption was 37,180 gpd, about 1.5 times the 1977 daily average consumption of 24,564 gpd. Table I-48 indicates average and peak month daily average comined water consumption for 1974-1977.

TABLE I-48. 1974-1977 WATER CONSUMPTION RECORDS FOR THE COMBINED OPERATIONS OF HART COUNTY CREAMERIES AND WHEYCO INC.

Year	Daily Average Water Consumption (gpd)	Daily Average Water Consumption During Peak Month (gpd)	Peak Month to Average Ratio
1974	23,128	40,732	1.8
1975	26,526	56,583	2.1
1976	30,777	41,529	1.3
1977	24,564	37,180	1.5
Mean	26,249	44,006	1.7

1977 DAILY AVERAGE WATER CONSUMPTION BY MONTH FOR HART COUNTY CREAMERIES AND WHEYCO

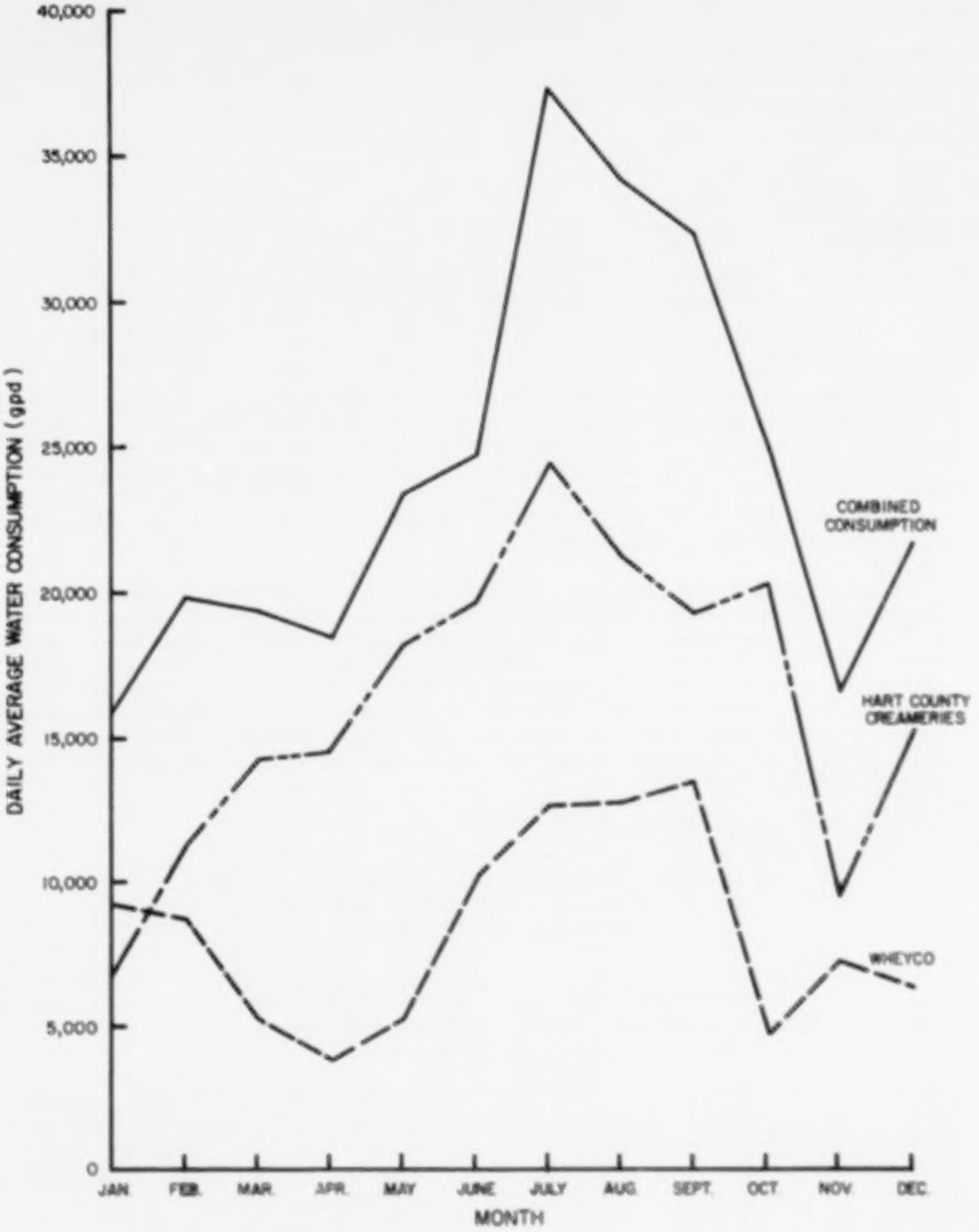


FIGURE T

The water consumption data in Table I-48 indicate that annual operations at Hart County Creameries and Wheyco are reasonably consistent. However, greater variations may occur during peak months as evidenced by the average daily water consumption of 56,583 gpd in August of 1975.

Equipment washdown accounts for nearly all water consumption at Hart County Creameries and Wheyco. In addition, it is estimated that approximately 90% of water consumption is discharged as wastewater to the Horse Cave sewerage system. Using the mean water consumptions in Table I-48, this translates to an annual daily average wastewater discharge of about 23,600 gpd and a peak seasonal discharge of 39,600 gpd. Although the seasonal variations in wastewater flow are only a small percentage of hydraulic loading at the wastewater treatment plant, because of their high BOD's, the extra organic loading may significantly affect the treatment plant. In addition, they occur coincidently with increased loadings due to summer tourist activities. Furthermore, since the largest volumes of wastewater are used at the end of a shift, most of the day's wastewater volume may be discharged within the span of a few hours. It is likely that some type of flow equalization will be required to prevent shock-loads to the Horse Cave wastewater treatment plant.

There is little information regarding the characteristics of the wastewaters resulting from these operations. According to a Kentucky Division of Water Quality memo of October 25, 1976, from Mr. C. P. Baldwin to Mr. W. S. Forester, the piping arrangement at the creamery prevents obtaining a true evaluation of the discharge. Wastewaters are generally high in BOD and have a low pH, however, no detailed information is available to indicate how waste load varies throughout the dav. The only data available are the results of grab samples collected and analyzed by the Kentucky Division of Water Quality. These are indicated in Table I-49.

The wastewater characteristics indicated by the data in Table I-49 (especially BOD and pH) demonstrate that wastewaters from Hart County Creameries and Wheyco have the potential to significantly impact wastewater treatment in the Horse Cave treatment plant. In order to evaluate these potential impacts, a detailed study and determination of flow variation, quantity and quality of the Creameries' and Wheyco's wastewaters is necessary.

On-Lot Treatment Disposal Systems

In areas unserved by municipal sewerage facilities, individual homes and businesses rely on some method of subsurface on-lot treatment/disposal. Because the underlying rock formations in the area consist primarily of cavernous limestone with free-flow groundwaters, the potential for groundwater pollution from these types of systems is apparent. In fact, the general method of wastewater disposal until recent years was to discharge untreated wastewater directly to openings in the rock. This practice is changing as septic tanks with absorption fields are presently installed with new construction. However, because of the soil/rock formations, septic tank effluents may drain directly to the groundwaters with little or no treatment in the soils.

The overall effect of these discharges on groundwater quality is undetermined as little is known about the assimilative capacity of the underground streams. However, several instances of fecal contamination of individual domestic water supplies are reported (Figure I-77). Because groundwaters in limestone aquifers generally move rapidly with little natural purification, wastewaters and other pollutants introduced to the groundwater may contaminate wells located "downstream" in the hydraulic gradient.

Most of these on-lot systems are scattered throughout the rural areas of the region minimizing impacts on groundwater quality. However, the municipality of Park City constitutes a large source of untreated waste water entering the groundwater system. Local health department officials indicate that about 80% of the residences and businesses in Park City discharge untreated wastewater directly to the subsurface, while the remaining 20% have septic tanks followed by direct discharge.

Wastewaters from Park City have been traced to Echo River in Mammoth Cave and could pose a threat to the water quality in the cave systems of the national park. Although not necessarily a question of public health, the problems associated with Park City's wastewater is the danger of destroying a national resource. In rural areas, the potential for well contamination from wastewater discharges appears to be the greater issue.

Financial Programs

Sewer Rates. Sewer rates in the study area are all based upon a percentage of the users water bill. Sewer rates in the municipalities within the study area are determined as follows:

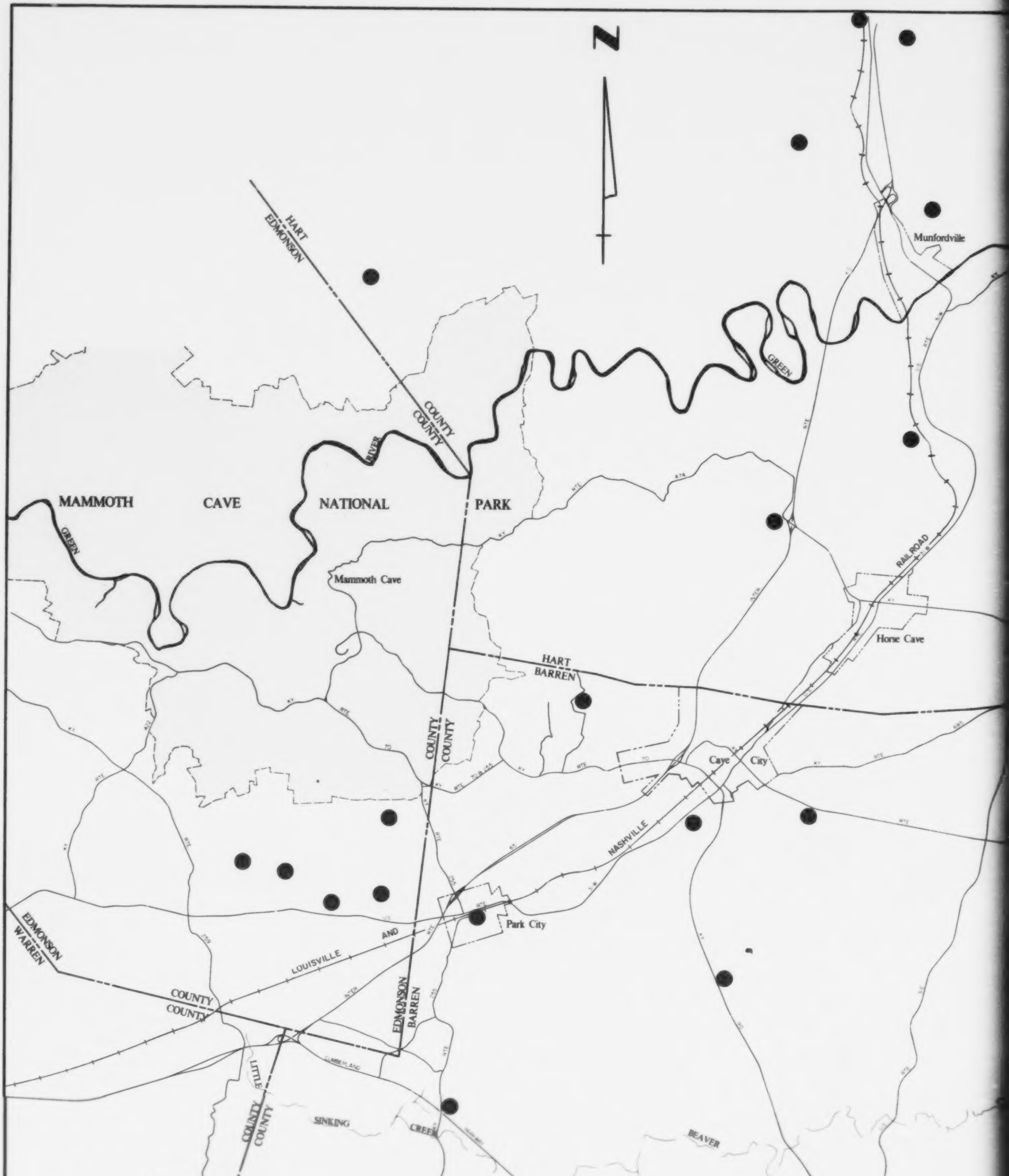
Horse Cave	-	50% of Water Bill
Cave City	-	80% of Water Bill
Mammoth Cave	-	75% of Water Bill

Water rates schedules upon which the sewer rates are based are presented in the Water Supply Section.

Bonded Indebtedness. All of the municipalities have incurred bonded indebtedness in order to finance both water and sewer facilities. Table I-50 presents an outline of the existing sewer and water bonded indebtedness for each municipality in the study area.

Wastewater Flow Projections

Wastewater flow projections were obtained directly from the water consumption projections in the Water Supply Section. For estimating purposes, it is assumed that wastewater flows are 90% of the water consumption. The difference is due to water consumption which does not result in spent wastewaters discharged to the wastewater collection system (eg. car washing and lawn watering). The only data available for any population in the study area are Cave City's water consumption and wastewater flow records for the months of April - September, November and December, 1977. These data tend to substantiate the 90% assumption, since during these months, wastewater flows averaged about 87% of water consumption by sewered customers. It is assumed that this 90% is not only applicable to the residential/commercial communities of Cave City, Park City and Munfordville, but is also useful in estimating industrial wastewater flows in Horse Cave and those associated with visitation in the National Park.


N
HART
EDMONSON
COUNTY
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Munfordville
GREEN
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MAMMOTH
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NATIONAL
PARK
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Mammoth Cave
RAILROAD
Horse Cave
HART
BARREN
COUNTY
COUNTY
Cave
City
NASHVILLE
EDMONSON
WARREN
Park City
LOUISVILLE
AND
COUNTY
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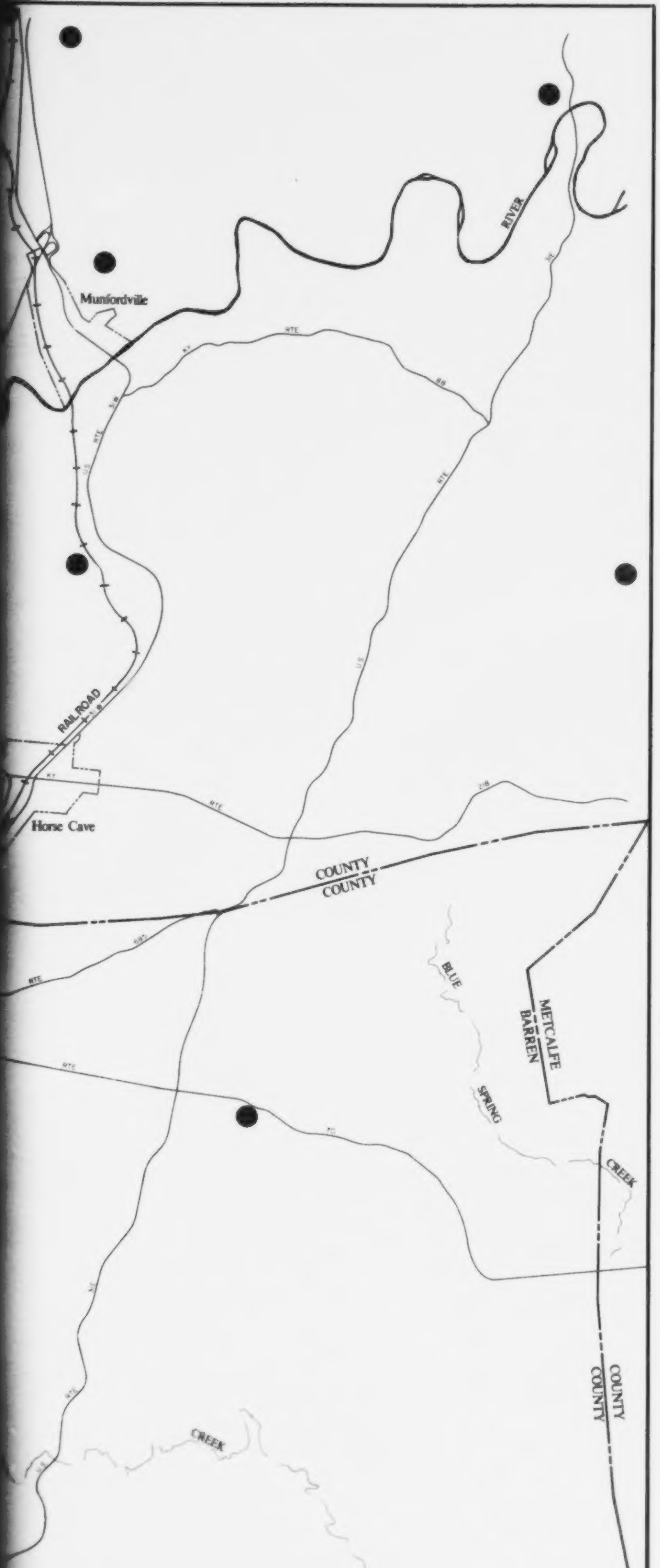
Munfordville
RIVER
RAILROAD
Horse Cave
COUNTY
COUNTY
BLUE
SPRING
CREEK
METCALFE
BARREN
COUNTY
COUNTY
CREEK

LEGEND

▨ MAMMOTH CAVE NATIONAL PARK

NOTE: THESE MAY NOT REPRESENT ALL POINTS OF WELL CONTAMINATION IN THE AREA. SAMPLES ARE COLLECTED ONLY UPON REQUEST OF THE WELL OWNER, GENERALLY WHEN CONTAMINATION IS SUSPECTED. HEALTH DEPARTMENT OFFICIALS INDICATE 60-70% OF THOSE WELLS SAMPLED ARE CONTAMINATED BY FECAL POLLUTION.

FIGURE I-77

MAMMOTH CAVE AREA
201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

CONTAMINATED WELL SITES

12,000 6000 0 12,000 24,000
Scale In Feet

U.S. Environmental Protection Agency
Region IV Atlanta, Georgia

B

Infiltration/inflow was not considered in developing wastewater flow projections. This is due to a lack of flow data for existing wastewater treatment facilities and because infiltration/inflow work for the 201 study has not started. Infiltration/inflow, however, is not considered to be significant for preliminary design considerations in Cave City, Horse Cave or Mammoth Cave National Park. This is because process design is to be based on the peak seasonal organic loading which occurs during the summer months when infiltration/inflow is minimal. Since Park City has no existing sewerage system, consideration of infiltration/inflow is not applicable. However, for Munfordville, consideration should be given to I/I as soon as data becomes available.

Table I-51 indicates wastewater flow projections for each of the study area population centers. These flows represent the total wastewater generated by water consumption in each population center. They do not include allowance for I/I in sewered areas.

Special Problem Areas

Non-Point Sources of Pollution

Land use in the study area outside the National Park is primarily agricultural. Agricultural activities, such as the use of fertilizers and pesticides or large scale livestock production, constitute a major potential non-point source of pollution. In these karst areas, these wastes are carried into the groundwater through sinkholes, seepage through depressions or via sinking streams which drain agricultural areas.

The greatest immediate pollution threat is the contamination of groundwater supplies. However, other adverse effects on water pollution may result. The magnitude of the problem in the study area is undetermined, but there is no doubt that agricultural runoff contributes a substantial waste load to the groundwater. In the study area, livestock production is the main agricultural activity. The BRADD Comprehensive Water and Sewer Plan of 1973 estimates 62,400 cattle and 33,500 pigs are in Barren County, a population equivalent of about 800,000 people. Even if only one-tenth of these are in the study area, this equivalent of 70,000 is still greater than the peak seasonal human population for the entire study area. Besides cattle and pigs, BRADD reports that sheep and poultry also contribute to wastes generated by farm animals.

Contamination from Oil Wells

Oil production in western Kentucky during 1958-1960 resulted in the production of waste brines that were improperly disposed of throughout the years. Drilling in the Greensburg oilfield, which is thirty miles east of Munfordville and outside of the EIS study area, caused brine contamination of the Green River and groundwaters. This contamination moved downstream and into the EIS study area. By November 1958 there was contamination of the groundwaters around Mammoth Cave at Echo and Styx Rivers. Chloride concentrations in the Green River at Munfordville averaged 3.9 mg/l prior to contamination and 257 mg/l after contamination (1958-1959) (Krieger and Hendrickson, 1960). Present (1978) chloride concentrations average 9.2 mg/l, which indicates that brine contamination in the Green River from oil wells upstream from Munfordville may no longer be a problem.

Within the EIS study area two sites of local oil well contamination have been documented. High Sulfate contents measured in the Parker River Cave system are interpreted to be derived from oil wells (Table I-52).

TABLE I-52. SULFATE CONTENTS IN
PARKER RIVER CAVE SYSTEM

	Sulfate Content mg/l		
	Quinlin	GFCC Sampling	
Location		Moderate Flow	Low Flow
Brown River	5	6	-
Parker River	250	128	-
North Creek	2	7	14
Sulfur River			
upstream Phantom	44	-	-
Phantom*	2750	-	247
downstream Phantom	660	-	246

* Site where water from local oil well leaks into the cave.

Sources: Quinlan, J. F. and D. R. Rowe, 1978 Research Report No. 109. University of Kentucky, Water Resources Research Institute

GFC&C, Inc. groundwater sampling program

Quinlan (1978) states that during the 1920's approximately 30-40 oil wells produced oil in the area. Casing was rarely set, and some that was set was allegedly pulled during the 1930's. The result has been local contamination of the groundwater. Families in this area presently rely on water piped from Glasgow and springs. Water samples from Mill Hole, the site to which Parker Cave streams flow, indicate little or no brine contamination (10 mg/l sulfate, 9 mg/l chloride). Dilution is probably the major reason for the lowered sulfate and chloride levels. Quinlan has also noted that, during base flow conditions, high sulfate and chloride concentrations in Hick Spring indicate contamination by a local oil well. In general, water contamination from oil wells in the area is localized and not a serious problem.

The issue of these non-point waste sources is not whether these wastes should be controlled, but rather whether their impacts on water quality are great enough as to overshadow impacts of point sources. Some attempt to assess the impacts of agricultural runoff is necessary in order to help determine if improved treatment and disposal of point sources will result in significant water quality improvements. Some discussion of non-point source pollution is provided in Section

9 of this report, Subsurface Water Resources. However, a complete analysis of non-point source pollution is beyond the scope of this EIS.

References:

Hopkins, H. T., 1963. The Effect of Oilfield Brines on the Potable Ground Water in the Upper Big Pitman Creek Basin, Kentucky. Kentucky Geological Survey.

Krieger, R. A. and G. E. Hendrickson. 1960. Effects of Greensburg Oilfield Brines on the Streams, Wells and Springs of the Upper Green River Basin, Kentucky. Kentucky Geological Survey.

Quinlan, J. F. and D. R. Rowe. 1978. Research Report No. 109. Hydrology and Water Quality in the Central Kentucky Karst: Phase II Part A. Water REsources Research Institute. University of Kentucky.

9. WATER SUPPLY

There are three major sources of water supply in the study area: groundwater, groundwater springs and the Green River. Groundwater wells are used extensively for home water supplies in areas unserved by public supplies. In addition groundwater is used for semi-public supplies such as camp grounds and motels. However, past experience (e.g. Park City) indicates that groundwater wells are generally not adequate for public and/or industrial water supplies. Because of the complexity of the groundwater regime, the quantity and quality of groundwater is unpredictable. The quality of groundwater may change drastically as it moves through certain subsurface formations and areas of chemical or biological contamination. In the study area there are problems with salt water intrusion, sulfate and salt water pollution from petroleum extraction activities in the area, and pollution resulting from animal or human wastes. Because of the nature of the groundwater flow regime, groundwaters are extremely vulnerable to pollution via runoff draining through sinkholes or direct discharge of wastes to the groundwaters. (Figure I-77) indicates known areas of fecal contamination as determined by the Barren and Edmonson-Hart County Health Departments. Although there appear to be adequate groundwater supplies for home use, use of this type of water supply is expected to decrease as the public supply service area continues to expand into rural areas.

There are many locations on the Green River or tributaries where groundwater emerges from its subsurface drainage in free-flowing springs. Several of these provide large quantities of water year-round while others with smaller drainage areas flow only during wet-weather periods. These groundwater springs presently provide a source of water supply in Mammoth Cave National Park and as the source of water supply for the Green River Valley Water District. According to the Mammoth Cave Master Plan, however, the National Park is slated to construct water treatment facilities to use the Green River as the supply. This decision was prompted by the heavy demands generated by park visitation resulting in lowering of the water level in the Caves, thus, endangering cave biota. Rio Spring, near Caverna, Kentucky, serves as the source of water supply for the Green River Valley Water District. The Rio Spring provides water of good quality and an estimated minimum flow of 4 mgd.

The Green River serves as the water supply for the Edmonson County Water District (serving Park City) and, as previously mentioned, is to be used as the service of water for the National Park. With a 7-day, 10 year low flow of about 209 cfs at Brownsville, the Green River appears to have sufficient yield to serve the entire study area. However, since the Green River Basin is largely an unprotected watershed, the supply is subject to pollution from runoff as well as point source discharges.

There are three public water supply systems in the study area; Mammoth Cave National Park, Edmonson County Water District and the Green River Valley Water District. Table I-53 provides information regarding the source of water supply, average and maximum demands, service area description and treatment capacity. Each of the municipalities in the study area operates its own water distribution system (Table I-54).

The following is an outline of the water rate schedules for each municipality:

HORSE CAVE

QUANTITY	RATES
0 - 1,000 GALLONS	$3.50 MINIMUM
1,001 - 5,000 GALLONS	$1.65 PER THOUSAND
5,001 - 10,000 GALLONS	$1.55 PER THOUSAND
10,001 - 20,000 GALLONS	$1.30 PER THOUSAND
20,001 - 30,000 GALLONS	$1.20 PER THOUSAND
30,001 - 50,000 GALLONS	$0.90 PER THOUSAND
OVER - 50,000 GALLONS	$0.55 PER THOUSAND

CAVE CITY

MINIMUM BILL	$3.95 1999
2,000 - 5,000	$1.20 PER THOUSAND
5,000 - 10,000	$1.10 PER THOUSAND
10,000 - 20,000	$1.00 PER THOUSAND
20,000 - 30,000	$0.90 PER THOUSAND
30,000 - 40,000	$0.70 PER THOUSAND
40,000 - 80,000	$0.60 PER THOUSAND
80,000 -	$0.55 PER THOUSAND

Table I-53

PUBLIC WATER SUPPLIES IN STUDY AREA

Water Supply	Source of Water	*Service Area	Approximate Number of Connections	(1977) Average Daily Pumpage (mg)(m³day)	(1977) Maximum Daily Pumpage (mg)(m³day)	Treatment Capacity (mg)(m³day)	Treatment	Future Planning
Green River Valley Water District	Rio Spring Canmer, Kentucky	Rural areas of Barren and Hart Counties; supply to municipalities of Munfordville, Horse Cave, Cave City, and Hiseville	3447	1.18 (4467)	1.349 (5107)	2 (7570)	Conventional	Green River Valley Water District is currently seeking funds to expand the treatment plant to 4 mgd. Presently adding about 600 new customers.
Edmonson County Water District	Green River Brownsville, Kentucky	Rural areas of Edmonson County; Brownsville, Park City	960	0.36 (1363)	0.5 (189)	0.5 (189)	Conventional	The Edmonson County Water District water treatment plant will be expanded to 1 mgd by May 1979 to accommodate an anticipated 800 additional customers.
Mammoth Cave National Park				National Park All system 1973 Ave. Day For August 0.418 (1582)	Estimated Maxi. Day 0.65 (2461)			By the year 2000, use of existing sources of water will be discontinued. The Park master plan calls for treating water from the Green River to supply the needs of the Park. The treatment plant capacity is to be about 0.7 mgd.
A. Maple Springs System	Spring	Maple Springs Ranger Station	-	-	-	-	Cl_2	
B. Great Onyx Job Corps Center System	Cooper Springs Collins Springs	Job Corps Center Facilities	-	-	-	-	Cl_2	
C. Mt. McKinley System	Cooper Springs Collins Springs	Southeastern section of National Park	-	-	-	-	Cl_2	
D. Flint Ridge System	Bransford Springs Bransford Well Adwell Springs	Park Headquarters area and main cave entrance facilities	-	-	-	-	Cl_2	

Source: Comprehensive Water and Sewer Plan
Personal communication, Green River Valley Water District
Personal communication, Edmonson County Water District
Mammoth Cave National Park Master Plan

MUNFORDVILLE

RATES	SEWERED	UNSEWERED
<2000 gal.	$8.48	$4.85-Min. Charge of $4.85
Next 8,000(to 10,000 gal.)	$3.15/1000 gal.	$1.80/1000 gal.
Next 10,000(to 20,000 gal.)	$2.97/1000 gal.	$1.70/1000 gal.
Next 10,000(to 30,000 gal.)	$2.62/1000 gal.	$1.50/1000 gal.
Next 10,000(to 40,000 gal.)	$2.45/1000 gal.	$1.40/1000 gal.
Next 20,000(to 60,000 gal.)	$2.10/1000 gal.	$1.20/1000 gal.
Next 40,000(to 100,000 gal.)	$1.40/1000 gal.	$ .80/1000 gal.
100,000	$ .87/1000 gal.	$ .50/1000 gal.

PARK CITY

Minimum $6 for first 2,000 gallons

$1.25/1000 gals. for next 8,000 gallons
$1.00/1000 gals. for next 30,000 gallons
$ .80/1000 gals. for next 50,000 gallons
$ .60/1000 gals. for > 90,000 gallons

Water Consumption

Because of the influence of tourism in the study area, water consumption in the population centers of Horse Cave, Cave City and Park City fluctuate significantly during the year. Due to the large industrial consumption in Horse Cave, however, seasonal variation is not as evident here. For each of these municipalities there are three demands to consider; (1) average daily consumption for the entire year, (2) average daily consumption during the peak month of the tourist season, and (3) maximum daily consumption for the year. Since Munfordville is not significantly affected by tourism, only average day and maximum day consumptions are considered.

Extensive billing records are available for the municipalities of Cave City and Park City. These records for 1970-1977 indicate the monthly residential consumption, commercial consumption, as well as the consumption for each customer and number of connections (residential/commercial/industrial). Since water consumption data are limited for Munfordville and Park City, Horse Cave and Cave City data are used where applicable in estimating per capita or commercial consumptions. The methodology and assumptions used in developing water consumption projections are found in Appendix I.

Water consumption projections for each municipality are developed by estimating the following components of consumption:

1) Residential consumption

2) Commercial consumption associated with tourism (Cave City, Park City and Horse Cave)

3) Commercial consumption not associated with tourism

4) Industrial consumption (Horse Cave only)

For design purposes the average daily demand during the peak month of the tourist season and maximum daily demand are considered to be most important. Because Horse Cave, Cave City and Park City are affected most by non-resident population, a method of estimating commercial consumption associated with tourist demand for those communities is developed in Appendix I. Peak seasonal consumption is based on these calculations and projected increases in Mammoth Cave National Park visitation. Maximum daily consumption is developed by multiplying the average consumption during the peak month by a factor of 1.4. This reflects the approximate maximum/average ratio in park visitation during the peak season and also a typical maximum to average ratio for small water systems. Water consumption projections for each municipality are found in Table I-55.

Water consumption projections for Mammoth Cave National Park are based on past water demands and the development suggested by the master plan. Although no additional concession facilities are slated for the historic area of the park, those already located there are assumed to continue operation. As the new staging area is constructed, there will be two demand centers for the National Park; (1) those associated with the concessions, park administration offices, campground and employee residence area in the park and (2) the new staging area. For the purposes of projecting consumption, it is assumed that the staging area is constructed between 1980 and 1990. Water consumption projections for Mammoth Cave National Park appear in Table I-56. Appendix I contains the assumptions and methodology used in their development.

10. COMMUNITY SERVICES AND FACILITIES

Community services and facilities in the study area have been surveyed to determine their current level of services and their ability to serve the existing population. These services and facilities can either be affected by wastewater facilities planning through increases in population as a result of greater wastewater capacity or some of the services can, in fact, impact the planning of wastewater facilities. This inventory will review the major community services and facilities which are provided in the study area. These include: health services; public safety (police and fire protection); sanitation; education and libraries and tax structure.

Health Services

Barren County - The major health care facility in Barren County is the T. J. Samson Hospital in Glasgow. This is a 199 bed facility which provides a complete range of health facilities. The county also has one intermediate care nursing home providing 52 beds and two personal care homes providing 98 beds, with one home also providing an additional 20 extended care beds. There is a county health department which provides a variety of services. An inventory of health care manpower in the county is provided in Table I-57.

Hart County - The major health care facility in Hart County is the Caverna Memorial Hospital in Horse Cave. This is a 30 bed facility. There are no skilled nursing homes or intermediate care homes in the county but there is one home classified as a personal care home with a capacity of 54 beds. There is also a county health department. An inventory of health care manpower in the county is provided in Table I-57.

TABLE I-57

HEALTH CARE MANPOWER

County	Physicians	Dentists	Nurses	Optometrists	Pharmacists
Barren	31	9	187	4	28
Edmonson	2	1	8	-	1
Hart	13	3	36	2	8
TOTAL...	46	13	231	6	37

Source: BRADD Data Book, 1978

Edmonson County - There are few health care facilities located in the county. There are no hospitals in the county. There is one personal care home with a 37 bed capacity. The county has a small county health department which provides various public health related services. An inventory of health care manpower in the county is provided in Table I-57.

Public Safety

Fire Protection. Fire protection services in the study area are provided by volunteer fire departments located within the individual municipalities. Each of the municipalities in the study area including Cave City, Park City, Horse Cave and Munfordville have volunteer fire departments. Edmonson County maintains a county fire department but the other counties of Hart and Barren do not. The fire departments in Horse Cave and Munfordville have 4 and 5 pieces of equipment, respectively. There is no information available on the fire departments in Cave City or Park City.

Police Protection. Each county has a police department with a sheriff who is the principal law enforcement officer. Barren County has four police officers, Edmonson County has three, and Hart County has four. Each of the municipalities in the study area also has their own police department. Cave City has four police officers, Park City one, Horse Cave three, and Munfordville two police officers.

Sanitation

Barren County - Solid waste services are provided to Cave City and Park City by a private collection service that operates its own private approved sanitary landfill. Residents in rural areas are not served by any collection service. These residents may transport their solid waste to the Glasgow landfill and dispose of it on a fee basis. For residential customers, the collection frequency is weekly with a monthly fee of $3.25.

Edmonson County - A private collection service provides collection and disposal service to about half of the county's residents. This waste is being disposed of in an approved landfill in Grayson County. Another private collector serves portions of Barren, Warren and Hart counties and operates an approved disposal site in Edmonson County.

Hart County - One approved landfill is operated in Hart County by a private company. Private collection service is provided to Munfordville, Bonnieville and portions of rural Hart County.

Schools and Libraries

Each of the counties in the study area have a county public school system. In addition, an independent school system exists at Caverna, which includes students from the City of Horse Cave in Hart County and Cave City in Barren County. There are no private, parochial or other non-public educational facilities in the study area. Western Kentucky University in Bowling Green is the nearest college-level institution to the study area. Western Kentucky University is a state-supported institution with an enrollment of approximately 13,000 students.

Educational levels in the study area are exceedingly low. Table I-58 indicates median school years completed for each of the counties in the study area for 1960 and 1970. While educational levels have improved from 1960 to 1970 they continue to be below region, state and national median levels for years of school completed.

Table I-59 presents data on school enrollments in the study area from 1971 to 1977. School district enrollments in the study area have shown an overall decline but did show an increase in 1977. Individually, the Hart and Caverna Independent school districts have had slight enrollment decreases while the Barren and Edmonson school districts have had slight enrollment increases.

There are several libraries which are available to residents of the study area. The largest is the Mary Wood Weldon Memorial Library in Glasgow. This library has 35,490 volumes. This library has a branch in Cave City which is located in the municipal building. In Hart County there are two libraries located within the study area. The Hart County Public Library is located in Munfordville and has 24,486 volumes. The Horse Cave Free Public Library has 10,000 volumes. There is also the Edmonson Free Public Library located in Brownsville, which maintains a collection of 19,120 volumes.

Tax Structure

Property taxes provide the major source of income for state, county and local governments. Land and buildings are taxed by the state and may be taxed by local jurisdictions. The state rate is $0.015 per $100 of assessed valuation. Tangible personal property such as automobiles, trucks, finished goods, office furniture and office equipment which are owned by manufacturers are also taxed by the state at $0.15 per $100 and may be taxed by local jurisdictions.

The following table provides the local property tax rates per $100 of assessed valuation by the various taxing jurisdictions in the study area (Table I-60).

Utilities

The study area is serviced by a variety of utility companies who provide electric, natural gas and telephone service. Table I-61 outlines the provision of these services in the study area.

TABLE I-58.
EDUCATION LEVELS MEDIAN SCHOOL YEARS COMPLETED

County	1960	1970
Barren	8.1	8.6
Edmonson	7.4	8.4
Hart	8.1	8.5
BRADD	8.0	8.8
State of Kentucky	8.7	9.9
United States	10.6	12.1

Source: Integrated Program Design Barren River Area Development District, June, 1977.

11. OTHER PROJECTS AND PROGRAMS

Beyond the preparation of the 201 Wastewater Facilities Plan and the Wastewater Facilities Environmental Impact Statement, the following is an outline of projects and programs in the study area which are relevant to wastewater facilities planning and water quality management.

Green River Basin 303 (e) Plan

This is a basin wide plan prepared to comply with the Federal Water Pollution Control Act Amendments of 1972. The plan establishes the following:

- Existing water quality, specifying applicable standards for water quality.
- An analysis of planning programs conducted by Federal, state, regional and local agencies throughout the Green River Basin.
- Compliance schedules and target dates for the abatement of pollution from point sources and non-point sources.
- Specific needs and priorities for the construction of municipal wastewater treatment plants in the Green River Basin.

Comprehensive Water and Sewer Plan for the Barren River Area Development District

This is a regional plan for water and sewer facilities in the BRADD region. The planning, which was completed in 1973, includes recommendations for: upgrading existing wastewater facilities to comply with water quality criteria; extension of existing water systems; and consolidations of small water utilities.

Mammoth Cave National Park Master Plan

This plan was completed in April, 1975. The plan was prepared because of increasing travel in the park, changing public needs, and studies required by the Wilderness Act. These needs and requirements have necessitated a complete review of the park's development and management. The master plan addresses such park issues as park management, resource management and visitor usage. A major concern of the plan is preserving the environmental quality of the park while attempting to handle increasing park visitations. An environmental impact statement was also prepared in conjunction with the park's master plan.

Mammoth Cave National Park Transportation Study

This study, which is currently under way, is carrying out a directive of the master plan, namely the development of a transportation plan for the park. The plan is intended to alleviate congestion in the park. In conjunction with this study, detailed visitation projections are being developed.

MAMMOTH CAVE AREA, KENTUCKY

201 FACILITIES PLAN

ENVIRONMENTAL IMPACT STATEMENT

APPENDIX I

ENVIRONMENTAL INVENTORY

TECHNICAL REFERENCE DOCUMENT

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IV
ATLANTA, GEORGIA 30365

TABLE OF CONTENTS

Page

PART A. NATURAL ENVIRONMENT

Kentucky Water Quality Criteria for Aquatic Life, Public Drinking Water Supplies and Recreational Uses AI - 1

Results of Water Quality Sampling Program AI - 7

Fishes of Barren, Hart and Edmonson Counties AI - 13

Mussels of the Mammoth Cave Area EIS Study AI - 19

Results of the Invertebrate Sampling Program AI - 21

Crayfish Tissue - Metals Analysis Procedure AI - 40

Flora of the Mammoth Cave Study Area AI - 42

Wildlife of Mammoth Cave Study Area AI - 61

PART B. MAN-MADE ENVIRONMENT

Development of Present Population Estimates AI - 72

Development of Population Projections AI - 79

Estimation of Wastewater Flows as a Percentage of Water Consumption AI - 81

Water Consumption Data AI - 82

Water Consumption Projections AI - 87

Estimation of Year 2000 Motel Units and an Estimation of Tourist Related and Non-Tourist Related Commercial Water Consumption AI - 96

Mammoth Cave National Park Water Consumption AI - 98

LIST OF TABLES

PART A. NATURAL ENVIRONMENT

Page

AI-1 Temperature, Base Flow and Concentrations of BOD_5, Total Kjeldahl Nitrogen, Ammonia Nitrogen, Nitrate Nitrogen, Phosphorus and Ortho Phosphate at each Sampling Station during Moderate and Low Flow Grab Samples AI - 7

AI-2 MBAS, pH, Suspended Solids, Conductivity, Hardness, Chlorides, and Sulfates at each Sampling Station during Moderate and Low Flow Sampling Conditions AI - 8

AI-3 Heavy Metals Concentrations at Each Sampling Station during Moderate and Low Flow Conditions AI - 9

AI-4 Densities of Total Coliform, Fecal Coliform and Fecal Streptococci Bacteria, Fecal Coliform/Fecal Streptococci Values and Interpretations of those Ratios for Each Sampling Site at Moderate and Low Flow Sampling Conditions AI - 10

AI-5 Total Heavy Metals Calculations During Base and Moderate Flow Conditions AI - 11

AI-6 Long-Term Sampling Results - Average Value, Maximum and Minimum Values presented for Each Parameter at Each Sampling Site AI - 12

PART B. MAN-MADE ENVIRONMENT

Table

AI-7 Population Projections for Permanent Residents AI - 80

AI-8 Cave City Water Consumption/Wastewater Data for 8 Months in 1977 AI - 81

LIST OF FIGURES

PART B. MAN-MADE ENVIRONMENT

Figure		Following Page
AI-1	Graphical Representation of Population Estimates and Projections	AI - 80
AI-2	Horse Cave Water Consumption Data from Water Billing Records	AI - 82
AI-3	Cave City Water Consumption Data from Water Billing Records	AI - 84

PART A. NATURAL ENVIRONMENT

Kentucky Water Quality Criteria
for Aquatic Life, Public Drinking
Water Supplies and Recreational Uses.
Relates to: KRS Chapter 224.
Pursuant to: KRS 224.020 and 224.060

I. Minimum Criteria Applicable to All Surface Waters

The following minimum water quality criteria are applicable in stream to all surface waters including mixing zones. These criteria are applicable in the stream in the water column.

All surface waters shall be kept free from substances attributable to man discharges in concentrations that will:

A. Settle to form objectionable deposits.

B. Float as debris, scum, oil or other matter to form a nuisance.

C. Produce objectionable color, odor, taste or turbidity.

D. Injure, be toxic to or produce adverse physiological or behavioral responses in humans, fish, shellfish, and aquatic life.

Presently regulated toxic substances must not exceed:

Aldrin/Dieldrin	0.003 μg/l
Benzidine	0.1 μg/l
DDT	0.001 μg/l
Endrin	0.004 μg/l
Polychlorinated Biphenyls (PCBS)	0.001 μg/l
Toxaphene	0.005 μg/l

E. Produce undesirable aquatic life or result in the dominance of nuisance species;

F. Cause the gross total alpha particle activity (including radium-226 but excluding radon and uranium) to exceed 15 pCi/1.

G. Cause combined radium-226 and radium-228 to exceed 5 pCi/1 (provided that specific determinations of radium-226 and radium-228 are not necessary if dissolved gross particle activity does not exceed 5 pCi/1).

H. Cause the concentration of total gross beta particle activity to exceed 50 pCi/1, the concentration of tritium to exceed 20,000 pCi/L or the concentration of total Strontium-90 to exceed 8 pCi/1.

II. Aquatic Life

A. Warmwater Aquatic Habitat

Warmwater aquatic habitat means any surface water and associated substrate capable of supporting warmwater aquatic life existing naturally in a particular environment. The following parameters and their associated criteria are for the protection of productive, reproducing warmwater aquatic communities.

(1) Alkalinity. Natural alkalinity as $CaCO_3$ shall not be reduced by more than 25%. Where natural alkalinity is below 20 mg/l $CaCO_3$, no reduction below the natural level is allowed. Alkalinity shall not be reduced to a degree which may adversely affect the aquatic community.

(2) pH shall not be less than 6.0 nor more than 9.0 and shall not fluctuate more than one unit over a period of 24 hours.

(3) Flow shall not be altered to a degree which will adversely affect the aquatic community.

(4) Temperature shall not exceed 31.4 degrees Centigrade; 89 degrees Fahrenheit.

(i) The normal daily and seasonal temperature fluctuations that existed before the addition of heat due to other than natural causes shall be maintained.

(ii) The maximum temperature rise other than the effects of a mixing zone shall not exceed the natural temperature by 2.8^o Centigrade, 5^o Fahrenheit, with a maximum rate of change not to exceed 1^o Centigrade (1.8^o Fahrenheit) degrees per hour. The Department will maintain guidelines for maximum daily average temperatures based on available data. The Department may determine that deviations from these guidelines will be allowed upon the submission of adequate supporting data on naturally occurring temperatures. The allowable temperature increase in impounded waters shall be limited to 1.7^o Centigrade, 3^o Fahrenheit, above the natural seasonal norm.

(5) Dissolved Oxygen. A minimum concentration of 5 mg/l daily average and at no time should the instantaneous minimum be less than 4 mg/l. The dissolved oxygen concentration shall be measured at mid-depth in waters having a total depth of ten (10) feet or less and at a depth of five (5) feet in waters having a total depth of greater than ten (10) feet.

(6) Solids

(a) Total Dissolved Solids. Total dissolved solids shall not be changed to the extent that the aquatic community is adversely affected.

(b) Total Suspended Solids. Total suspended solids shall not be changed to the extent that the aquatic community is adversely affected. The addition of settleable solids that may adversely alter the stream bottom is prohibited.

(7) Ammonia. The concentration of the un-ionized form shall not be greater than .05 mg/l at any time in stream.

(8) Toxic Substances

(a) The allowable instream concentration of toxic substances which are short-lived or which have noncumulative effects shall not exceed 0.1 of the 96 hour median tolerance (LC_{50}) limit of a representative indigenous aquatic organism.

(b) The allowable instream concentration of toxic substances which are long-lived or bioaccumulation effects shall not exceed 0.01 of the 96 hour median tolerance limit (LC_{50}) of a representative indigenous aquatic organism.

(c) Discharged substances shall not injure, be toxic to or produce adverse physiological or behavioral responses in humans, animals or plants.

(d) The following are maximum allowable concentrations:

Metals

Arsenic	50 μg/l
Beryllium	1100 μg/l
Cadmium	12 μg/l
Chromium as Total Hexavalent	100 μg/l
Copper	0.1 times 96 hour LC50
Iron	1.0 mg/l*
Lead	0.01 times 96 hour LC50
Mercury	0.05 μg/l
Nickel	0.1 times 96 hour LC50
Selenium	.01 times 96 hour LC50
Silver	.01 times 96 hour LC50
Zinc	.01 times 96 hour LC50

Organics

Cyanide	5 μg/l
Phenol	1 μg/l
Phathalate Esters	3 μg/l
Pesticides	
Chlordane	0.01 μg/l
Demeton	0.1 μg/l
Endosulfan	0.003 μg/l
Guthion	0.01 μg/l
Heptachlor	0.001 μg/l
Lindane	0.01 μg/l

* For low streams, the daily average total iron concentration is limited to 3.5 mg/l when it is established by the applicant that there will be no irretrievable damage to aquatic life.

Malathion	.1 μg/l
Methoxychlor	0.03 μg/l
Paxathion	0.04 μg/l

Hydrogen Sulfide as undissociated	2 μg/l
Chlorine, Total Residual	10 μg/l

B. Coldwater Aquatic Habitat

Coldwater aquatic habitat are surface waters and associated substrate that will support indigenous aquatic life as well as stocked trout.

All of the criteria adopted for the protection of warmwater aquatic life also apply to the protection of coldwater habitats with the following exceptions:

(1) Dissolved Oxygen. A minimum concentration of 6 mg/l as a daily average and 5 mg/l as an instantaneous minimum shall be maintained at all times. In impoundments which support trout, the concentration of dissolved oxygen in waters below the epilimnion shall be kept consistent with natural water quality.

(2) Water temperature shall not be increased through man's activities above the natural seasonal temperatures. (Shade producing stream side vegetation is an integral part of trout stream habitat and helps maintain desirable water temperatures).

(3) The addition of settleable solids that alter the aquatic habitat so as to adversely impact the indigenous aquatic life is prohibited.

(4) The total chlorine residual shall not exceed .2 ug/l.

III. Public Water Supply

Public water supply is any surface water that with conventional treatment will be suitable for human consumption, culinary purposes, or in any food of beverage processing industry and meet State and/or Federal regulations for drinking water.

Arsenic	0.05 mg/l
Barium	1 mg/l
Ammonia (NH$_3$)	.05 mg/l
Cadmium	0.01 mg/l
Chromium Total	0.05 mg/l
Color	75 Platinum-Cobalt Color Units
Copper	1 mg/l
Cyanide	.005 mg/l
Fecal Coliform	2000/100 ml (Geometric Mean)
Iron	0.3 mg/l
Lead	0.05 mg/l
Manganese	0.05 mg/l
Mercury	0.002 mg/l

Methylene Blue	
Active Substances	0.5 mg/l
Nitrate (NO_3-N) as total	10 mg/l
Pesticides	
Chlordane	0.003 mg/l
Chloxophenoxy Herbicides	
2, 4-D	0.1 mg/l
2, 4, 5-TP	0.01 mg/l
Guthion	0.1 ug/l
Heptachlor	0.1 mg/l
Lindane	0.004 mg/l
Malathion	0.1 mg/l
Methoxychlor	0.1 mg/l
Parathion	0.1 mg/l
pH	5.0-9.0
Phenol	0.001 mg/l
Selenium	0.01 mg/l
Silver	0.05 mg/l
Zinc	5 mg/l
Fluoride, Total	1 mg/l
Chloride, Total	250 mg/l
Sulfate, Total	250 mg/l
Total Dissolved Solids	750 mg/l

IV. Recreational Use

A. Bathing Waters:

These are waters suitable for swimming where a lifeguard and/or bathhouse facilities are present during the recreation season. Fecal coliform content shall not exceed 200/100 ml as a monthly geometric mean based on no less than five samples per month; nor exceed 400 per 100 ml in more than ten percent of all samples taken during the month; these limits are applicable during the recreation season of May 1 through October 31. During November 1 through April 30, fecal content (either MPN or MF count) shall not exceed 1,000 per 100 ml as a monthly geometric mean based on not less than five samples per month; nor exceed 2,000 per 100 ml in more than ten percent of all samples taken during a month. pH shall be between 6.0 - 9.0 and shall not fluctuate more than one unit within this range over a period of 24 hours.

B. Primary Contact Recreation:

These are waters suitable for full body contact recreation, such as, but not limited to; swimming and scuba diving, with minimal threat to public health as a result of water quality, during the recreation season. Fecal Coliform content (either MPN or MF count) shall not exceed 1,000 per 100 ml as a monthly geometric mean based on not less than five samples per month; nor exceed 2,000 per 100 ml in more than ten percent of all samples taken during a month. pH shall be maintained between 6.0 - 9.0 and shall not fluctuate more than one pH unit within this range over a period of 24 hours.

C. Secondary Contact Recreation:

These are waters suitable for partial body contact recreation, such as, but not limited to: Canoeing and Wading, with minimal threat to public health as a result of water quality during the recreation season.

Fecal Coliform shall not exceed 5,000 per 100 ml in more than ten percent of the samples taken during any 30 day period.

pH shall be between 6.0 - 9.0 and shall not fluctuate more than one unit within this range over a period of 24 hours.

RESULTS OF WATER QUALITY SAMPLING PROGRAM

TABLE AI-1. TEMPERATURE, BASE FLOW AND CONCENTRATIONS OF BOD_5, TOTAL KJELDAHL NITROGEN, AMMONIA NITROGEN, NITRATE NITROGEN, PHOSPHORUS AND ORTHO PHOSPHATE AT EACH SAMPLING STATION DURING MODERATE AND LOW FLOW GRAB SAMPLES.

Sample Station	Temperature °C		Estimated Base Flow (cfs)	Dissolved Oxygen mg/1		BOD_5 mg/1		TKN mg/1 N		NH_3-N mg/1 N		NO_3-N mg/1 N		Total-P mg/1 (P)		Ortho-P mg/1 (P)	
	mod	low		mod	low	mod	low	mod	low	mod	low	mod	low	mod	low	mod	low
1.	13.8	18.0	0	10.4	8.2	2.7	3.0	1.1	*	0.3	0.16	0.56	0.60	0.076	0.12	0.004	0.03
2.	11.5	15.5	.04	10.6	7.9	1.7	1.5	0.7	*	0.3	0.04	0.75	0.39	0.042	0.08	0.006	0.01
3.	11.8	*	0	10.4	*	1.3	*	0.5	*	0.2	*	2.14	*	0.03	*	0.012	*
4.	11.8	16.0	.05	10.2	8.4	1.1	0.8	0.7	*	0.2	0.03	1.04	2.94	0.09	0.07	0.012	0.01
5.	*	*	*	*	*	1.5	0.2	0.4	*	<0.2	0.16	5.8	1.81	0.028	0.09	0.020	0.02
6.	*	*	*	*	*	2.0	0.7	<0.2	*	<0.2	0.11	2.52	5.36	0.02	0.06	0.014	0.03
7.	*	*	*	*	*	1.6	*	*	*	*	*	*	*	*	*	*	*
8.	*	<15.5	2.5	*	>8.4	2.3	0.0	0.5	*	<0.2	0.06	1.77	3.35	0.116	0.12	0.03	0.01
9.	*	*	.1	*	*	1.8	1.6	0.3	*	<0.2	0.05	2.82	6.50	0.046	0.08	0.02	0.07
10.	*	*	*	*	*	1.4	0.0	0.2	*	<0.2	0.07	3.98	4.00	0.026	0.12	0.014	0.01
11.	*	*	.1	*	*	*	*	*	*	*	*	*	*	*	*	*	*
12.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
14.	11.8	14.0	10	10.1	8.5	1.2	0.7	0.4	*	<0.2	0.03	2.14	3.05	0.076	0.10	0.022	0.04
15.	*	13.5	*	*	8.1	1.2	0.3	0.5	*	<0.2	0.01	2.33	6.87	0.048	0.10	0.022	0.04
16.	11.8	13.0	1.6	9.6	8.8	1.0	1.2	0.3	*	<0.2	0.11	1.84	1.09	0.028	0.06	0.018	0.01
17.	13.0	19.0	*	3.9	2.7	133	74	6.5	*	1.0	5.60	1.94	5.35	2.79	3.75	1.73	1.11
18.	12.8	15.0	*	9.9	7.9	1.2	8.9	0.4	*	0.3	0.65	3.79	3.95	0.08	0.67	0.054	0.52
19.	10.5	15.0	1.8	13.0	8.25	1.0	2.0	<0.2	*	<0.2	0.03	1.75	1.25	0.032	0.08	0.016	0.02
20.	13.8	13.8	.31	11.2	9.6	0.9	1.0	<0.2	*	<0.2	0.02	2.88	10.0	0.034	[illegible]	0.034	0.01
21.	10.6	14.0	15-20	12.5	2.5	1.0	1.2	0.3	*	<0.2	0.08	3.59	3.57	0.076	0.40	0.04	0.33
26.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
27.	*	*	*	*	*	304	340	66.5	*	[illegible]	23.5	12.4	1.16	14.8	*	14.2	*
28.	13.5	21.5	*	2.9	3.1	148	47	39.2	*	26.4	28.3	7.6	0.65	17.5	12.2	17.5	10.9
29.	*	*	*	*	*	316	59	22.5	*	6.8	4.64	8.0	4.54	10.5	*	10.4	*
30.	13.3	23.8	*	2.6	3.1	96	361	23.3	*	8.8	9.0	4.5	3.82	6.16	31.4	4.16	29.2

* sample not required

TABLE AI-2. MBAS, pH, TOTAL [illegible]NDED SOLIDS, CONDUCTIVITY, HARDNESS, CHLORIDES AND SULFATES AT EACH SAMPLING STATION DURING MODERATE AND LOW FLOW SAMPLING CONDITIONS

Sample Station	MBAS mg/1		pH		Total Suspended Solids(mg/1)		Total Dissolved Solids(mg/1)		Conductivity Micromhos/cm		Hardness mg/1 $CaCO_3$	Chloride mg/1		Sulfate mg/1 (SO_4)	
	mod	low	mod	low	mod	low	mod	low	mod	low		mod	low	mod	low
1	0.015	0.018	7.6	6.8	18	*	64	73	70	65	52	1	*	8	*
2	0.018	0.076	7.0	7.7	12	*	75	172	80	256	*	3	*	6	*
3	0.002	*	6.6	*	40	*	74	*	70	*	*	4	*	8	*
4	0.013	0.044	7.2	7.7	23	1.0	104	169	110	268	75	4	*	7	*
5	0.002	0.010	7.2	7.2	1.4	*	343	326	360	510	242	*	18	*	9
6	0.013	0.013	7.5	7.3	5.6	*	608	3400	550	5130	253	200	*	136	*
7	*	*	7.2	7.5	6.4	*	557	2410	500	4260	257	184	1180	26	20
8	0.013	0.030	7.2	7.5	29	1.7	164	296	160	525	136	5	*	6	*
9	0.037	0.017	7.3	7.3	17	*	560	2520	600	3740	252	180	*	128	*
10	0.007	0.003	7.4	7.3	14	13	222	475	250	706	222	5	94	7	14
11	*	*	*	7.1	*	*	*	7950	*	12800	*	*	3850	*	246
12	*	*	*	7.3	*	*	*	18620	*	26000	*	*	8920	*	247
14	0.023	0.003	7.3	7.5	32	3.0	205	380	240	553	142	9	*	10	*
15	0.008	0.008	7.3	7.8	38	*	183	279	220	440	157	5	37	9	13
16	0.003	0.005	7.4	7.9	4.2	0.7	171	181	170	244	147	2	*	9	*
17	0.022	0.091	7.2	7.1	49	17	402	649	340	988	188	18	*	91	*
18	<0.002	0.018	7.2	7.3	10	6.7	227	436	230	576	197	5	*	10	*
19	<0.002	0.005	7.5	8.0	8	4.7	136	403	140	338	102	2	*	7	*
20	0.008	0.000	7.2	7.3	4.4	0.7	198	287	210	452	196	2	*	3	*
21	<0.002	0.003	7.2	7.3	8	5.3	220	367	240	635	189	6	*	10	*
26	*	*	7.0	8.5	70	*	493	578	400	1098	*	*	*	*	*
27	2.91	*	7.9	6.9	65	*	517	*	560	736	*	*	*	*	*
28	5.86	0.558	7.1	7.5	108	30	506	438	560	776	197	*	*	*	*
29	0.79	*	7.2	7.4	155	*	1338	*	460	1383	*	*	*	*	*
30	1.86	0.521	7.3	6.4	41	151	496	1650	400	1720	176	*	*	*	*

*no sample required

TABLE AI-3. HEAVY METALS CONCENTRATIONS AT EACH SAMPLING STATION DURING MODERATE AND LOW FLOW CONDITIONS

Sample Station	Total Iron mg/l		Total Nickel mg/l		Total Copper mg/l		Total Zinc mg/l		Total Chromium mg/l		Hexavalent Chromium mg/l	
	Mod.	Low	Mod.	Low	Mod.	Low	Mod.	Low	Mod.	Low	Mod.	Low
1	2.45	*	<0.02	*	<0.02	*	0.06	*	<0.02	*	<0.005	*
2	*	*	*	*	*	*	*	*	*	*	*	*
3	*	*	*	*	*	*	*	*	*	*	*	*
4	3.01	0.16	<0.02	*	<0.02	*	0.068	*	<0.02	*	<0.005	*
5	0.34	*	<0.02	*	<0.02	*	0.052	*	<0.02	*	0.01	*
6	0.46	*	<0.02	*	<0.02	*	0.032	*	<0.02	*	<0.005	*
7	0.46	*	<0.02	*	<0.02	*	0.028	*	<0.02	*	<0.005	*
8	1.50	*	<0.02	<0.01	<0.02	0.03	0.036	0.02	<0.02	<0.01	<0.005	0.004
9	0.74	*	<0.02	*	<0.02	*	0.108	*	<0.02	*	<0.005	*
10	0.45	*	<0.02	*	<0.02	*	0.052	*	<0.02	*	<0.005	*
11	*	*	*	0.07	*	0.04	*	0.03	*	0.03	*	*
12	*	0.15	*	0.15	*	0.04	*	0.02	*	0.13	*	*
14	1.05	*	<0.02	*	<0.02	*	0.024	*	<0.02	*	<0.005	*
15	0.66	*	<0.02	<0.01	<0.02	0.01	0.068	0.02	<0.02	<0.01	<0.005	*
16	0.33	*	<0.02	*	<0.02	*	0.024	*	<0.02	*	<0.005	*
17	0.36	*	0.05	0.48	0.68	0.14	0.116	0.07	2.37	0.22	0.63	0.018
18	0.45	*	<0.02	0.03	<0.02	<0.01	0.048	0.02	<0.02	0.07	<0.005	0.028
19	0.57	*	<0.02	*	<0.02	*	0.052	*	<0.02	*	<0.005	*
20	0.15	*	<0.02	<0.01	<0.02	<0.01	0.072	0.01	<0.02	0.03	<0.005	*
21	0.45	*	<0.02	<0.01	<0.02	0.02	0.028	0.03	<0.02	0.02	<0.005	*
26	0.63	*	29.4	0.79	9.1	0.69	1.32	0.21	34.7	0.91	30.0	0.440
27	1.45	*	<0.02	*	0.10	*	0.400	*	0.24	*	0.03	*
28	0.75	*	<0.02	*	0.03	*	0.188	*	0.02	*	0.02	*
29	0.83	*	20.8	*	7.9	*	0.92	*	25.8	*	10.7	*
30	0.78	*	12.8	3.57	6.6	0.59	0.584	0.35	16.7	2.42	7.9	0.06

* No Sample

TABLE AI-4. DENSITIES OF TOTAL COLIFORM, FECAL COLIFORM AND FECAL STREPTOCOCCI BACTERIA, FECAL COLIFORM/FECAL STREPTOCCI VALUES AND INTERPRETATIONS OF THOSE RATIOS FOR EACH SAMPLING SITE AT MODERATE AND LOW FLOW SAMPLING CONDITIONS.

Sample Station	Total Coliform No/100 ml		Fecal Coliform No/100 ml		Fecal Streptococci No/100 ml		FC/FS		Interpretations and Comments on FC/FS	
	Mod	Low	Mod	Low	Mod	Low	Mod	Low	Moderate	Low Flow
1	-	1,200	20	1,000	50	100	.4	10	of limited value; ≤ 100 organisms	of limited value; ≤ 100 organisms
2	-	230	420	200	400	420	1.05	.48	questionable; borderline ratio	indicates animal pollution
3	-	*	2,730	*	920	*	2.97	*	indicates human pollution	
4	-	10,800	1,420	1,500	790	400	1.80	3.75	indicates human pollution	indicates human pollution
5	70	40	0	10	0	850	0	0.01	of limited value; < 100 organisms	of limited value; < 100 organisms
6	20	90	0	0	0	1,720	0	0	of limited value; ≤ 100 organisms	of limited value; ≤ 100 organisms
7	*	*	*	*	*	*	*	*		
8	900	720	570	30	300	1,900	1.90	0.02	indicates human pollution	of limited value; ≤ 100 organisms
9	100	2,000	30	120	10	160	3	.75	of limited value; ≤ 100 organisms	questionable, borderline ratio
10	10	70	0	0	0	240	0	0	of limited value; ≤ 100 organisms	of limited value; ≤ 100 organisms
11	*	*	*	*	*	*	*	*		
12	*	*	*	*	*	*	*	*		
14	520	250	320	120	130	1,000	2.46	.12	indicates human pollution	indicates animal pollution
15	750	60	140	0	0	100	0	0	of limited value; ≤ 100 organisms	of limited value; ≤ 100 organisms
16	150	20	30	10	0	70	0	.14	of limited value; ≤ 100 organisms	of limited value; ≤ 100 organisms
17	6,200	100,000	30	85,000	0	150,000	0	.57	of limited value; ≤ 100 organisms	indicative of creamery & sewage wastes
18	1,060	20,000	70	17,500	0	60,000	0	.29	of limited value; ≤ 100 organisms	indicates animal pollution or possible contamination from #17
19	760	350	70	180	0	400	0	.45	of limited value; ≤ 100 organisms	indicates animal pollution
20	40	110	0	100	0	280	0	.36	of limited value; ≤ 100 organisms	of limited value; ≤ 100 organisms
21	0	10	0	0	0	0	0	0	of limited value; ≤ 100 organisms	of limited value; ≤ 100 organisms
26	*	*	*	*	*	*	*	*		
27	*	*	*	*	*	*	*	*		
28	-	**	100,000	**	33,000	**	3.03		indicates human pollution	
29	*	*	*	*	*	*	*	*		
30	-	200,000	**	120,000	**	1,000,000		.12		indicates creamery & sewage wastes

- defective growth medium
* no sample taken
** sample not properly preserved

TABLE AI-5

TOTAL HEAVY METALS CALCULATIONS USING THE RELATIONSHIP[1]

$\frac{Ca}{La} + \frac{Co}{Lb} \ldots + \frac{Cn}{Ln} \leq 1$ DURING BASE AND MODERATE FLOW CONDITIONS

Sampling Station	Moderate Flow		Low Flow	
	Calculation[2]	Conservative Calculation[3]	Calculation[2]	Conservative Calculation[3]
1	1.0	1.8	*	*
4	1.0	1.9	*	*
5	.9	1.6	*	*
6	.8	1.2	*	*
7	.8	1.1	*	*
8	.8	1.3	.8	1.1
9	1.3	2.7	*	*
10	.9	1.6	*	*
11	*[4]	*	1.7	2.1
12	*	*	2.4	2.7
14	.8	1.1	*	*
15	1.0	1.9	.4	.7
16	.8	1.1	*	*
17	14.9	16.4	8.1	9.0
18	.9	1.6	.6	.9
19	.9	1.6	*	*
20	1.1	2.0	.4	.5
21	.8	1.1	.7	1.1

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[1] Ca, Cb, ... Cn are the measured concentration for each metal;
La, Lb, Lc are the established limits for each metal.

[2] L_{Ni} = 0.1 mg/1
L_{Cu} = 0.05 mg/1
L_{Zn} = 0.15 mg/1, limit for warmwater fish

[3] L_{Ni} = 0.1 mg/1
L_{Cu} = 0.05 mg/1
L_{Zn} = 0.05 mg/1, limit for cold water fish

[4] * = no sample

TABLE AI-6
LONG-TERM SAMPLING RESULTS
AVERAGE VALUE, MAXIMUM AND MINIMUM VALUES PRESENTED FOR EACH PARAMETER AT EACH SAMPLING SITE

Sampling Site	Base Flow cfs 10*	Temp oC 10*	Dissolved O_2 mg/1 10*	Conductivity μmho 10*	TKN mg/1 4*	NH_3-N mg/1 5*	NO_3-N mg/1 5*	Nickel mg/1 10*	Chromium mg/1 10*	Copper mg/1 10*	Zinc mg/1 10*
4	.3 .09 .05	24.1 16.7 11.2	9.5 7.9 5.6	305 295 268	0.22 0.17 0.12	0.05 0.034 0.02	2.9 0.78 0.16	-	-	-	-
14	10 5.8 5.0	14.5 14.0 13.5	13.3 8.9 6.9	604 545 390	0.38 0.21 0.08	0.05 0.036 0.02	3.05 2.42 1.60	-		-	-
17	1 1 1	20.5 18.2 16.0	4.4 3.2 2.6	1320 1124 [illegible]	11.7 8.67 6.9	6.75 6.04 5.50	7.38 3.09 0.23	2.94 0.82 0.15	0.34 0.24 0.08	0.61 0.32 0.07	0.29 0.13 0.05
18	7.0 5.8 4.0	15.0 14.3 13.8	10.0 8.3 6.8	650 602 562	1.12 0.92 0.60	0.65 0.42 0.05	7.74 4.17 2.75	-	-	-	-
19	4.0 2.6 1.0	24.2 16.4 12.0	13.4 9.0 7.4	385 361 301	0.35 0.30 0.27	0.3 0.09 0.03	3.62 1.34 0.24	-	-	-	-
20	4.0 2.7 1.5	13.9 13.6 13.1	12.9 10.9 9.6	480 467 445	0.25 0.18 0.13	0.2 0.07 0.01	10.0 4.71 2.9	-	-	-	-
30	-	-	-	-	-	-	-	3.57 1.61 0.27	2.42 0.69 0.36	1.06 0.57 0.09	0.51 0.26 0.15

* Number of samples taken at each station
- No samples taken

FISHES OF MAMMOTH CAVE STUDY AREA

FISHES OF MAMMOTH CAVE STUDY AREA

SUPERCLASS AGNATHA
Class PETROMYZONES
Order Petromyzontiformes
Family Petromyzontidae
Genus *Icthyomyzon* Girard
    Ichthyomyzon *bdellium* (Jordan). Ohio lamprey
    Ichthyomyzon *greeleyi* Hubbs & Trautman. Allegheny brook lamprey
    Ichthyomyzon *unicuspis* Hubbs & Trautman. Silver lamprey[3]
Genus *Lampetra* Bonnaterre
    Lampetra *aepyptera* (Abbott). Least brook lamprey[2]
    Lampetra *lamottei* (LeSueur). American brook lamprey

SUPERCLASS GNATHOSTOMATA
Class OSTEICHTHYES
Order Acipenseriformes
Family Acipenseridae
Genus *Acipenser* Linnaeus
    Acipenser *fulvescens* Rafinesque. Lake sturgion
Family Polyodontidae
Genus *Polyodon* Lacepede
    Polyodon spathula (Walbaum). Paddlefish[3]
Order Lepisosteiformes (=Semionotiformes)
Family Lepisosteidae
Genus *Lepisosteus* Lacepede
    Lepisosteus osseus (Linnaeus). Longnose gar 2,3
    Lepisosteus platostomus Rafinesque. Shortnose gar 3

Order Clupeiformes
Family Clupeidae
Genus *Alosa* Link
    Alosa chrysochloris (Rafinesque). Skipjack herring 3
Genus *Dorosoma* Rafinesque
    Dorosoma cepedianum (LeSueur). Gizzard shad 2,3

Family Esocidae
Genus *Esox* Linnaeus
Esox americanus vermiculatus LeSueur. Grass pickerel 2,3
Esox masquinongy Mitchill. Muskellunge 3
Family Hiodontidae
Genus *Hiodon* LeSueur
Hiodon alosoides (Rafinesque). Goldeye 3
Hiodon tergisus leSueur. Mooneye 2,3,

Order Cypriniformes
Family Catostomidae
Genus *Ictiobus* Rafinesque
Ictiobus bubalus (Rafinesque). Smallmouth buffalo 3
Ictiobus cyprinellus (Valenciennes). Bigmouth buffalo 3
Genus *Carpiodes* Rafinesque
Carpiodes carpio (Rafinesque). River carpsucker 3
Carpiodes cyprinus (LeSueur). Quillback 3
Genus *Catostomus* LeSueur
Catostomus commersoni (Lacepede). White sucker 2
Genus *Hypentelium* Rafinesque
Hypentelium nigricans (LeSueur). Northern hog sucker 2,3
Genus *Erimyzon* Jordan
Erimyzon oblongus (Mitchill). Creek shubsucker
Erimyzon sucetta (Lacepede). Lake chubsucker
Genus *Minytrema* Jordan
Minytrema melanops (Rafinesque). Spotted sucker
Genus *Moxostoma* Rafinesque
Moxostoma anisurum (Rafinesque). Silver redhorse
Moxostoma carinatum (Cope). River redhorse
Mosostoma duquesnei (LeSueur). Black redhorse
Moxostoma erythrurum (Rafinesque). Golden redhorse
Moxostoma macrolepidotum breviceps (Cope). Southern shorthead redhorse
Moxostoma macrolepidotum macrolepidotum (LeSueur) Northern shorthead redhorse

Family Cyprinaae
Genus *Cyprinus* Linnaeus
Cyprinus carpio Linnaeus. Carp 2,3

- Genus *Carassius* Nilsson
    - *Carassius auratus* (Linnaeus). Goldfish 2
- Genus *Chrosomus* Rafinesque (=Phoxinus Rafinesque)
    - *Chrosomus erythrogaster* Rafinesque. Redbelly dace
- Genus *Semotilus* Rafinesque
    - *Semotilus atromaculatus* (Mitchill). Creek chub 2
- Genus *Rhinichthys* Agassiz
    - *Rhinichthys atratulus* (Hermann). Blacknose dace
- Genus *Nocomis* Girard
    - *Nocomis effusus* Lachner & Jenkins. Redtail chub
    - *Nocomis micropogon* (Cope). River chub 2
- Genus *Hybopsis* Agassiz
    - *Hybopsis aestivalis* (Girard). Speckled chub 3
    - *Hybopsis amblops* (Rafinesque). Bigeye chub 2,3
    - *Hybopsis dissimilis* (Kirtland). Streamline chub 2,3
    - *Hybopsis storeiriana* (Kirtland). Silver chub 3
- Genus *Notropis* Rafinesque
    - *Notropis ardens* (Cope). Rosefin shiner 2
    - *Notropis ariommus* (Cope). Popeye shiner 2,3
    - *Notropis atherinoides* Rafinesque. Emerald shiner 2,3
    - *Notropis boops* Gilbert. Bigeye shiner 2
    - *Notropis cornutus chrysocephalus* (Rafinesque). Central common shiner 2,3
    - *Notropis leuciodus* (Cope). Tennessee shiner 2
    - *Notropis lutrensis* (Baird & Girard). Red shiner
    - *Notropis photogenis* (Cope). Silver shiner 2,3
    - *Notropis rubellis* (Agassiz). Rosyface shiner 2,3
    - *Notropis spilopterus* (Cope). Spotfin shiner 2,3
    - *Notropis umbratilis* (Girard). Redfin shiner
    - *Notropis volucellus* (Cope). Mimic shiner 2,3
    - *Notropis whipplei* (Girard). Steelcolor shiner 2,3
- Genus *Phenacobius* Cope
    - *Phenacobius mirabilis* (Girard). Suckermouth minnow
    - *Phenacobius uranops* Cope. Stargazing minnow 2,3
- Genus *Pimephales* Rafinesque
    - *Pimpephales notatus* (Rafinesque). Bluntnose minnow 2,3
    - *Pimpephales promelas* Rafinesque. Fathead minnow 2
    - *Pimpephales vigilax* (Baird & Girard). Bullhead minnow 2,3
- Genus *Hybognathus* Agassiz
    - *Hybognathus nuchalis* Agassiz. Silvery minnow 3
- Genus *Campostoma* Agassiz
    - *Campostoma anomalum* (Rafinesque). Stoneroller 2,3

Family Ictaluridae

- Genus *Ictalurus* Rafinesque
    - *Ictalurus melas* (Rafinesque). Black bullhead 2,3
    - *Ictalurus natalis* (LeSueur). Yellow bullhead 2,3
    - *Ictalurus punctatus* (Rafinesque). Channel catfish 2,3
- Genus *Pylodictis* Rafinesque
    - Pylodictus olivaris (Rafinesque). Flathead catfish 2,3
- Genus *Noturus* Rafinesque
    - *Noturus elegans* Taylor. Elegant madtom
    - *Noturus eleutherus* Jordan. Mountain madtom 2
    - *Noturus exilis* Nelson. Slender madtom 2
    - Noturus flavus Rafinesque. Stonecat

Noturus miurus Jordan. Brindled madtom 2,3
Notropis nocturnis Jordan & Gilbert. Freckled madtom 2,3
Noturus stigmosus Taylor. Northern madtom

Order Cyprinodontiformes
Family Cyprinodontidae
Genus *Fundulus* Lacepede
Fundulus catenatus (Storer). Northern studfish 2
Fundulus notatus (Rafinesque). Blackstripe topminnow 2,3

Family Poecilidae
Genus *Gambusia* Poey
Gambusia affinis (Baird & Girard). Mosquito fish

Order Percopsiformes
Family Amblyopsidae
Genus *Chologaster* Agassiz
Chologaster agassizi Putnam. Karst springfish
Genus *Typhlichthys* Girard
Typhlichthys subterraneus Girard. Lesser blindfish
Genus *Amblyopsis* DeKay
Amblyopsis spelaea DeKay. Mammoth Cave blindfish

Order Muguliformes (=Atheriniformes, part)
Family Atherinidae
Genus *Labidesthes* Cope
Labidesthes sicculus (Cope). Brook silverside 2,3

Order Perciformes
Family Serranidae (=Percichthyidae)
Genus *Morone* Mitchill
Morone chrysops (Rafinesque). White bass 3
Morone mississippiensis Jordan & Eigenmann. Yellow bass
Morone saxatilis (Walbaum). Striped bass

Family Centrarchidae
Genus *Micropterus* Lacepede
Micropterus dolomieui Lacepede. Smallmouth bass 2,3
Micropterus punctulatus (Rafinesque). Spotted bass 2,3
Micropterus salmoides (Lacepede). Largemouth bass 2,3
Genus *Chaenobryttus* Gill
Chaenobryttus gulosus (Cuvier) = Lepomis gulosus (Cuvier) Warmouth 2,3
Genus *Lepomis* Rafinesque
Lepomis cyanellus Rafinesque. Green sunfish 2,3
Lepomis humilis (Garard). Orangespotted sunfish 3
Lepomis macrochirus Rafinesque. Bluegill 2,3
Lepomis megalotis (Rafinesque). Longear sunfish 2,3
Lepomis microlophus (Gunther). Redear sunfish 2,3
Genus *Ambloplites*
Ambloplites rupestris (Rafinesque). Rock bass 2,3
Genus *Pomoxis* Rafinesque
Pomoxis annularis Rafinesque. White crappie 2,3
Pomoxis nigromaculatus (LeSuer). Black crappie 2,3

Family Percidae
Genus *Stizostedion* Rafinesque
Stizostedion canadense (Smith). Sauger 2,3
Stizostedion vitreum vitreum (Mitchill). Walleye 2,3
Genus *Percina* Haldeman
Percina caprodes (Rafinesque). Logperch 2,3
Percina copelandi (Jordan). Channel darter 3
Percina cymatotaenia (Gilbert & Meek). Bluestripe darter 2,3
Percina evides (Jordan & Copeland). Gilt darter
Percina macrocephala (Cope). Longhead darter 2,3
Percina maculata (Girard). Blacside darter 2,3
Percina phoxocephala (Nelson). Slenderhead darter 2,3
Percina sciera (Swain). Dusky darter 2,3
Percina shumardi (Girard). River darter
Percina uranidea (Jordan & Gilbert). Stargazing darter
Genus *Ammocrypta* Jordan
Ammocrypta asprella (Jordan). Crystal darter
Ammocrypta pellucida (Putnam). Eastern sand darter
Genus *Etheostoma* Rafinesque
Etheostoma asprigene (Forbes). Mud darter
Estheostoma atripinne (Jordan). Snubnose darter
Etheostoma barbouri Kuehne & Small. Teardrop darter
Etheostoma bellum Zorach. Orangefin darter
Etheostoma blennioides Rafinesque. Greenside darter 2,3
Etheostoma caeruleum Storer. Rainbow darter 2,3
Etheostoma camurum (Cope). Bluebreast darter 2,3
Etheostoma chlorosomum (Hay). Bluntnose darter
Etheostoma flabellare Rafinesque. Fantail darter 2
Etheostoma kennicotti (Putnam). Stripetail darter 2,3
Etheostoma maculatum Kirtland. Spotter darter 3
Etheostoma microperca Jordan & Gilbert. Least darter
Etheostoma nigrum Rafinesque. Johnny darter 2
Etheostoma spectabile (Agassiz). Orangethroat darter
Etheostoma squamiceps Jordan. Spottail darter
Etheostoma stigmaeum (Jordan). Speckled darter 2,3
Etheostoma virgatum Jordan. Striped darter
Etheostoma zonale (Cope). Banded darter 2,3

Family Sciaenidae
Genus *Aplodinotus* Rafinesque
Aplodinotus grunniens Rafinesque. Freshwater drum 3

Family Cottidae
Genus *Cottus* Linnaeus
Cottus carolinae (Gill). Banded sculpin 2,3

1 - Fish expected in the study area.
2 - Fish collected in the study area.
3 - Fish collected outside the study area but within the Green River System.

Sources:

Clay, W.M. 1975. The Fishes of Kentucky. Kentucky Dept. of Fish and Wildlife Resources; Frankfort, Ky. 416 pp.

Charles, J.R. 1964. Effects of Oilfield Brines Proc. 18th Ann. Conf., S.E. Assoc. Game and Fish Comm. 63 pp.

MUSSELS OF THE STUDY AREA

MUSSELS OF THE STUDY AREA

Phylum Mollusca
Class Pelecypoda
Order Eulamellibranchiata

	REFERENCE			
	1	2	3	4
Family Corbiculidae				
Corbicula fluminea - Asiatic clam	x	x	x	x
Family Margaritiferidae				
Cumerlandia monodonta - Spectacle case				x
Family Unioniidae				
Subfamily Anodontinae				
Alasmidonta marginata - Elk Toe				x
Alasmidonta viridis - slipper shell				x
Anodonta ferussacianus - small floater	x			
Anodonta grandis grandis - floater				x
Anodonta imbecillis - paper pond shell				x
Arcidens confragosus - rock pocketbook		x		x
Lasmigona costata - fluted mussel	x	x	x	x
Lasmigona complanata - white heel splitter		x		x
Simpsonaias ambigua - Simpson's shell				x
Strophitus undulatus undulatus - square foot				x
Subfamily Lampsilinae				
Actinonaias carinata - mucket mussel	x			
Actinonaias ligamentina - mucket mussel	x	x	x	x
Carunculina parva - Lilliput mussel	x			
Cyprogenia stegaria - fan shell				x
Dysnomia Triquetra	x			
Epioblasma sulcata sulcata				x
Epioblasma triquetra - snuffbox				x
Lampsilis anodontoides - yellow sand shell	x	x		x
Lampsilis cariosa		x	x	
Lampsilis fallaciosa - slough sand shell	x			x
Lampsilis fasciola				x
Lampsilis luteola - fat mucket	x	x	x	
Lampsilis orbiculata - pink mucket pearly mussel				x
Lampsilis ovata - pocketbook	x	x	x	x
Lampsilis radiata - fat mucket	x			x
Lampsilis ventricosa - pocket book				x
Leptodea fragilis - fragile paper shell				x
Leptodea laevissima - paper shell	x	x		
Leptodea leptodon				x
Ligumia recta - black sand shell	x	x	x	x
Obliquaria reflexa - three horn	x	x	x	x
Obovaria olivaria - egg shell	x	x	x	x
Obovaria retusa - golf stick	x	x	x	x
Obovaria subrotunda	x	x	x	x
Plagiola lineolata - butterfly		x	x	x
Potamilus alatus - pink heel splitter				x
Potamilus laevissimus - fragile heel splitter				x
Proptera alata - pink heel splitter	x	x	x	

	REFERENCE			
	1	2	3	4
Proptera *capax* - pocketbook	x	x		
Ptycholbranchus *fasciolare* - kidney shell	x	x	x	x
Toxolasma *parvus* - lilliput shell				x
Truncilla *donaciformis* - fawn's foot	x	x	x	x
Truncilla *truncata* - deertoe	x	x		x
Villosa *fabalis*				x
Villosa *iris* *iris* - rainbow shell				x
Villosa *lienosa* *lienosa*				x
Villosa *ortmanni*				x
Subfamily Unioninae				
Amblema *costata* - three ridge	x	x	x	
Amblema *plicata* *plicata* - three ridge				
Cyclonaias tuberculata - pink pimpleback	x		x	x
Elliptio *crassidens* - mule ear	x	x	x	x
Elliptio *dilatatus* - lady finger	x		x	x
Fusconaia *ebeng* - neggerhead	x	x	x	x
Fusconaia *flava* - wabash pigtoe	x			x
Fusconaia *subrotunda* - long solid	x	x	x	x
Fusconaia *undata* - pigtoe	x	x	x	
Hemistena *lata*				x
Megalonqias *gigantea* - washboard	x	x	x	
Megalonqius *nervosa* - washboard				x
Plethobasus *cyphus* - bull head	x		x	x
Pleurobema *clava*		x		
Pleurobema *coccineum* - round pigtoe			x	x
Pleurobema *cordatum* - pigtoe	x	x	x	x
Pleurobema *plenum* - pigtoe		x	x	x
Pleurobema *pyramidatum* - pyramid pig-toe				x
Quadrula *cylindrica* - rabbit's foot	x			x
Quadrula *metanevra* - monkeyface	x	x		x
Quadrula *nodulata* - wartybacd	x		x	x
Quadrula *pustulosa* - white pimpleback	x	x	x	x
Quadrula *guadrula* - maple leaf	x	x	x	x
Tritogonia *verrucosa* - pistol grip	x	x	x	x

REFERENCES

1: Williams, J. C. 1969. Mussel Fishery Investigation, Tennessee, Ohio and Green River - Final Report. State of Kentucky Project No. 4-19-R. Kentucky Department of Fish and Wildlife Resources. 107 pp. - Area #1 Green River from Green-Taylor County lines to the last downstream riffle inside the east boundary of Mammoth Cave National Park (103 miles).

2: Williams, J. C. 1969. - Area #2 Green River from last downstream riffle to Dam 4 at Woodbury, Kentucky (54 miles).

3: Williams, J. C. 1969. - Area #3 Green River from Dam 4 to the mouth of the River (149 miles).

4: Patch, D. C. 1976. An Analysis of the Archaelogical shell of Fresh Water Mollusks from the Carlston Annis Shellmound West Central Kentucky. Thesis, Washington University; St. Louis, Mo. 66 pp + Appendices.

RESULTS OF THE INVERTEBRATE SAMPLING PROGRAM

PROJECT: Mammoth Cave Area EIS

SITE: GR-M Above #1

SAMPLE TYPE: Surber (3X)

DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Cheumatopsyche sp.		X		42	150.7	
Hydropsyche frisoni	X			2	7.2	
Corydalis sp.		X		1	3.6	
Tricorythodes sp.		X		2	7.2	
Caenis		X		1	3.6	
Chiron #1		X		4	14.4	Polypedilum sp.
Chiron #2		X		3	10.0	Rheotanytarsus sp.
Chiron #3		X		3	10.8	Orthocladius sp.
Chiron #4		X		1	3.6	Tanytarsus sp.
Hydroptilid e	X			2	7.2	Very small
Anculosa sp.		X		2	7.2	
Simulium luggusi		X		1	3.6	Pupae
Simulium luggusi				2	7.2	Larvae
Diptera Pupae			X	3	10.8	
Unknown Diptera			X	2	7.2	
Corbicula sp.			X	5	17.9	
Stenelmis sp.		X		2	7.2	Larvae
				1	3.6	Adult
Isonychia sp.	X			4	14.4	
Baetis sp.		X		3	10.8	
Stenorema sp.		X		12	43.1	
	3	13	3			
TOTAL 19				100	358.8	

$\bar{h}$ 2.08 e 0.29

PROJECT: Mammoth Cave Area EIS

SITE: GR-M Above #2

SAMPLE TYPE: Surber (3X)

DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Hydropsyche frisoni	X			5	17.9	
Cheumatopsyche sp.		X		38	136.3	
Hydropsyche sp.	X			4	14.4	
Corydalis sp.		X		2	7.2	
Simulium luggusi		X		2	7.2	Pupae
Tricorythodes sp.		X		6	21.5	
Isonychia sp.	X			6	21.5	
Baetis sp.		X		5	17.9	
Stenonema sp.		X		15	53.8	
Laeurpex sp.			X	2	7.2	
Corbicula sp.			X	4	14.4	
Chiron #1		X		6	21.5	Orthocladius sp.
Chiron #2		X		2	7.2	Polypedilum sp.
Chiron #3		X		5	14.4	Tanytarsus sp.
Chiron #4		X		3	10.8	Rheotanytarsus sp.
TOTAL 15	3	10	2	104	373.2	

$\bar{h}$ 3.20 e 0.87

PROJECT: Mammoth Cave Area EIS SITE: GR-M - Above #3

SAMPLE TYPE: Surber (3X) DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Cheumatopsyche sp.		X		49	175.8	
Hydroptilidae	X			4	14.4	
Tricorythodes sp.		X		18	64.6	
Caenis sp.		X		3	10.8	
Isonychia sp.	X			8	28.7	
Stenonema sp.		X		13.	46.6	
Baetis sp.		X		7	25.1	
Corbicula sp.			X	4	14.4	
Diptera Pupae			X	2	7.2	
Stenelmis sp.		X		1	3.6	Larvae
Chiron #1		X		4	14.4	Polypedilum sp.
Chiron #2		X		4	14.4	Orthocladius sp.
Chiron #3		X		1	3.6	Tanytarsus sp.
TOTAL 13	2	9	2	118	423.4	

$\bar{h}$ 2.81 e 0.77

PROJECT: Mammoth Cave EIS

SAMPLE TYPE: Surber (3 X)

SITE: GR-M-Below #1

DATE 3 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Tricorythodes sp.		X		8	28.7	
Cheumatopsyche sp.		X		52	186.6	
Corydalis sp.		X		1	3.6	
Hydropsyche frisoni	X			4	14.4	
Caenis sp.		X		1	3.6	
Anculosa sp.		X		2	7.2	
Corbicula sp.			X	5	17.9	
Stenonema sp.		X		23	82.5	
Baetis sp.		X		1	3.6	
Isonychia sp.	X			5	17.9	
Diptera Pupae			X	4	14.4	
Simulium luggus		X		1	3.6	Pupae
				2	7.2	Larvae
Chiron 1		X		8	28.7	Tanytarsus sp.
Chiron 2		X		3	10.8	Orthocladius sp.
Chiron 3		X		1	3.6	Polypedilum sp.
TOTAL 15	2	11	2	121	434.2	

$\bar{h}$ 2.82 e 0.67

PROJECT: Mammoth Cave EIS

SITE: GR-M-Below #2

SAMPLE TYPE: Surver (3 X)

DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Tricorythodes sp.		x		17	61.0	
Ephemera sp.	X			1	3.6	
Cheumatopsyche sp.		X		7	25.1	
Caenis sp.		X		1	3.6	
Anculosa sp.		X		3	10.8	
Corbicula sp.			X	12	43.1	
Laevapex sp.			X	14	50.2	
Stenonema sp.		X		52	186.6	
Hydroptila sp.	X			7	25.1	
Stenelmis sp.		X		1	3.6	Adult
				2	7.2	Larvae
Diptera pupae			X	2	7.2	
Chiron 1		X		11	39.5	Orthocladius sp.
Chiron 2		X		8	28.7	Tanytarsus sp.
Chiron 3		X		2	7.2	Polypedilum sp.
TOTAL 14	2	9	3	142	509.5	

$\bar{h}$ 3.09 e 0.89

PROJECT: Mammoth Cave EIS

SITE: GR-M-Below- #3

SAMPLE TYPE: Surber (3 X)

DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Cheumatopsyche sp.		X		17	61.0	
Tricorythodes sp.		X		22	78.9	
Hydropsyche frisoni	X			1	3.6	
Caenis sp.		X		1	3.6	
Polycentropus sp.		X		1	3.6	
Baetis sp.		X		2	7.2	
Isonychia sp.	X			2	7.2	
Stenonema sp.		X		28	100.5	
Laevipex sp.			X	6	21.5	
Stenelmis sp.		X		1	3.6	larvae
Ancyronyx variegatus	X			1	3.6	larvae
Unknown Diptera			X	1	3.6	small Musidae?
Diptera Pupae			X	1	3.6	
Agapetus sp.	X			2	7.2	
Corbicula sp.			X	1	3.6	
Anculosa sp.		X		7	25.1	
Chiron #1		X		7	25.1	Rheotanytarsus sp.
Chiron #2		X		8	28.7	Orthocladius sp.
TOTAL 18	4	10	4	109	391.1	

$\bar{H}$ 3.24

e 0.75

PROJECT: Mammoth Cave EIS

SITE: Hicks Spring #1

SAMPLE TYPE: Surber (3 X)

DATE: 3 October 1978

TAXON	I	F	T	NO.	DENS,	COMMENTS
Hydropsyche frisoni	X			33	118.4	
Caenis sp.		X		6	21.5	
Cheumatopsyche sp.		X		92	330.1	
Corydalis sp.		X		1	3.6	
Tricorythodes sp.		X		14	50.2	
Hydropsyche sp.	X			23	82.5	small
Corbicula sp.			X	2	7.2	
Stenonema sp.		X		9	32.3	
Isonychin sp.	X			4	14.4	
Simulium sp.		X		1	3.6	small
Bactis sp.		X		3	10.8	
Stenelmis sp.		X		2	7.2	larvae
Deptera Pupae			X	7	25.1	
Chiron 1		X		39	139.9	Orthocladius sp.
Chiron 2		X		24	86.1	Polypedilum sp.
Chiron 3		X		19	68.2	Tanytarsus sp.
Chiron 4		X		4	14.4	Pseudoorthocladius sp.
Chiron 5	X			2	7.2	Corynoneura sp.
TOTAL 18	4	12	2	288	1033.4	

$\bar{h}$ 3.37 e 0.83

PROJECT: Mammoth Cave EIS

SITE: Hicks Spring #2

SAMPLE TYPE: Surber (3 X)

DATE: 3 Oct. 1978

TAXON	I	F	T	NO.	DENS,	COMMENTS
Cheurmatopsyche sp.		X		64	229.6	
Hydropsyche frisoni	X			19	68.2	
Tricorythodes sp.		X		14	50.2	
Caenis sp.		X		4	14.4	
Hydroptilidae Pupae	X			1	3.6	
Corbicula sp.			X	4	14.4	
Anculosa sp.		X		3	10.8	
Stenelmis sp.		X		1	3.6	Adult
Simulium Complex		X		3	10.8	S. Meridionale
Diptera pupae			X	6	21.5	
Stenonema sp.		X		9	32.3	
Baetis sp.		X		15	53.8	
Isonychia sp.	X			4	14.4	
Calopteryx sp.		X		1	3.6	small
Chiron 1		X		32	114.8	Polypedilum sp.
Chiron 2		X		25	89.7	Orthocladius sp.
Chiron 3		X		3	10.8	Tanytarsus sp.
Chiron 4	X			2	7.2	Corynoneura sp.
Chiron 5		X		1	3.6	Pseudoorthocladius sp.
TOTAL 19	4	13	2	211	757.1	

$\bar{h}$ 3.28 e 0.74

PROJECT: Mammoth Cave Area EIS

SITE: [illegible]

SAMPLE TYPE: Surber (3 X)

DATE: 3 October 1978

TAXON	I	F	T	NO.	DENS,	COMMENTS
Tricorythodes sp.		X		29	104.1	
Hydropsyche frisoni	X			64	229.6	
Cheumatopsyche sp.		X		67	240.4	
Psephenus sp.		X		1	3.6	
Corydalis sp.		X		3	10.8	
Caenis sp.		X		9	32.3	
Anculosa sp.		X		5	17.9	
Corbicula sp.			X	7	25.1	
Laevipex sp.			X	1	3.6	
Diptera Pupae			X	14	50.2	
Simulium luggeri		X		4	14.4	pupae
				29	104.1	larvae
Simulium sp.		X		1	3.6	larvae
Stenelmis sp.		X		5	17.9	larvae
				1	3.6	adult
Isonychia sp.	X			12	43.1	
Baetis sp.		X		18	64.6	
Stenonema sp.		X		64	229.6	
Hydroptila sp.	X			1	3.6	
Polycentropus sp.		X		1	3.6	
Hydropsyche sp.	X			43	154.3	
TOTAL (Cont'd						

$\bar{h}$ 3.49 e 0.70

PROJECT: Mammoth Cave Area EIS

SITE: Hicks Spring #3

SAMPLE TYPE: Surber (3X)

DATE: 3 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Chiron 1		X		49	175.8	Orthocladius sp.
Chiron 2		X		11	39.5	Polypedilum sp.
Chiron 3		X		6	21.5	Pseudoorthocladius sp.
Chiron 4		X		30	107.6	Rheotanytarsus sp.
TOTAL 23	4	16	3	475	1704.3	

h 3.49

e 0.70

PROJECT: Mammoth Cave Area EIS

SITE: Blue Springs#1

SAMPLE TYPE: Surber (3 X)

DATE: 4October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Chimarra sp.	X			3	10.8	
Hydropsyche sp.	X			10	35.9	
Cheumatopsyche sp.		X		9	32.3	
Hydropsyche sp.	X			1	3.6	
Hydropsyche bettini	X			4	14.4	
Psephenus sp.		X		1	3.6	
Tipula sp.			X	2	7.2	
Mystacidis sp.		X		2	7.2	
Simulium sp.		X		2	7.2	
Stenonema sp.		X		4	14.4	
Baetis sp.		X		6	21.5	
Chiron 1		X		4	14.4	Ablabesmyia sp.
Chiron 2		X		15	53.8	Stictochironomus
Chiron 3	X			3	10.8	Corynoneura sp.
Chiron 4		X		1	3.6	Orthocladius sp.
TOTAL 15	5	9	1	67	240.4	

$\bar{h}$ 3.45

e 1.00

PROJECT: Mammoth Cave Area EIS

SITE: Blue Springs #2

SAMPLE TYPE: Surber (3X)

DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS,	COMMENTS
Psephenus sp.		X		3	10.8	larvae
Ancyronyx variegatus	X			1	3.6	larvae
Diptera pupae			X	3	10.8	
Simulium sp.		X		1	3.6	
Tipula sp.			X	10	35.9	
Hydropsyche bettini	X			29	104.1	
Chimarra sp.	X			11	39.5	
Mystacides sp.		X		2	7.2	
Perlesta sp.		X		3	10.8	
Baetis sp.		X		15	53.8	
Stenonema sp.		X		15	57.4	
Cheumatopsyche sp.		X		17	61.0	
Chiron 1		X		52	186.6	Stictochironomus sp.
Chiron 2		X		2	7.2	Ablabesmyia sp.
Chiron 3	X			4	14.4	Corynoneura sp.
Chiron 4		X		6	21.5	Nanocladius sp.
TOTAL 16	4	10	2	173	620.7	

$\bar{h}$ 3.14 e 0.81

PROJECT: Mammoth Cave Area EIS

SITE: Blue Spring #3

SAMPLE TYPE: Surber (3X)

DATE: 4 October 1978

TAXON		I	F	T	NO.	DENS.	COMMENTS
Chimarra sp.		X			8	28.7	
Cheumatopsyche sp.			X		18	64.6	
Hydropsyche betteni		X			12	43.1	
Hydropsyche sp.		X			5	17.9	
Tipula sp.				X	1	3.6	
Simulium sp.			X		3	10.8	
Baetis sp.			X		3	10.8	
Isonychia sp.		X			2	7.2	
Stenonema sp.			X		8	28.7	
Chiron 1			X		29	104.05	Stictochironomus sp.
Chiron 2			X		7	25.1	Ablabesmyia sp.
Chiron 3		X			2	7.2	Corynoneura sp.
Chiron 4			X		1	3.6	Nanoclodius sp.
TOTAL	13	5	7	1	99	355.22	

h 3.08

e 0.92

PROJECT: Mammoth Cave Area EIS

SITE: Apple Grove #1

SAMPLE TYPE: Net

DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
H. betteni	X			1		
Cheumatopsyche sp.		X		3		
Calopteryx sp.		X		1		
Chimarra sp.	X			2		
Diptera Pupae			X	1		
Stenonema sp.		X		14		
Baetis sp.		X		2		
Habrophlebiades sp.	X			1		
TOTAL 8	3	4	1	25		

h̄ 2.16 e 0.75

PROJECT: Mammoth Cave Area EIS

SITE: Apple Grove #2

SAMPLE TYPE: Net

DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Rhagionidae			X	25		
Physa sp.			X	8		
Cheumopsyche sp.		X		5		
Baetis sp.		X		4		
Simulium sp.		X		1		
Chiron 1		X		4		Ablabesmyia sp.
Chiron 2	X			4		Thienemanniella sp.
Chiron 3		X		1		Tanytarsus sp.
Chiron 4		X		1		Orthocladius sp.
TOTAL 9	1	6	2	53.0		

$\bar{h}$ 2.41 e 0.81

PROJECT: Mammoth Cave Area EIS

SITE: Apple Grove #3

SAMPLE TYPE: Net

DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Rhagionidae			X	13		
Cheumatopsyche sp.		X		5		
Baetis sp.		X		4		
Habrophlebiodes sp.	X			1		
Simulium sp.		X		1		small
Physa sp.			X	3		
Diptera Pupae			X	1		
Chiron 1		X		1		Ablabesmyia sp.
Chiron 2	X			1		Thienemanniella sp.
TOTAL 9	2	4	3	30		

$\bar{h}$ 2.48

e 0.83

PROJECT: Mammoth Cave Area EIS

SITE: Mill Hole #1

SAMPLE TYPE: Surber (3X)

DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Cheumatopsyche sp.		X		8	28.7	small
Simulium sp.		X		1	3.6	small
Chiron 1		X		42	150.7	Polypedilum sp.
Chiron 2		X		32	114.8	Rheotanytarsus
Chiron 3		X		15	53.8	Orthocladius sp.
Chiron 4	X			5	17.9	Corynoneura sp.
Chiron 5		X		3	10.8	Ablabesmyia sp.
TOTAL 7	1	6	0	106	380.3	

$\bar{h}$ 2.15 e 0.86

PROJECT: Mammoth Cave Area EIS

SITE: Mill Hole #2

SAMPLE TYPE: Surber (3X)

DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Cheumatopsyche sp.		X		1	3.6	
Chiron 1		X		27	96.9	Polypedilum sp.
Chiron 2		X		8	28.7	Rheotanytarsus sp.
Chiron 3		X		6	21.5	Orthocladius sp.
TOTAL 4	0	4	0	42	150.70	

$\bar{h}$ 1.39 e 0.75

PROJECT: Mammoth Cave Area EIS
SITE: Mill Hole #3
SAMPLE TYPE: Surber (3X)
DATE: 4 October 1978

TAXON	I	F	T	NO.	DENS.	COMMENTS
Cheumatopsyche sp.		X		3	10.8	small
Simulium sp.		X		2	7.2	
Diptera Pupae			X	4	14.4	
Chiron 1		X		57	204.5	Polypedilum sp.
Chiron 2		X		29	104.1	Rheotanytarsus sp.
Chiron 3		X		14	50.2	Orthocladius sp.
Chiron 4		X		5	17.9	Ablabesmyia sp.
TOTAL 7	0	6	1	114	409.0	

h 1.98

e 0.71

CRAYFISH TISSUE - METALS ANALYSIS PROCEDURE

Crayfish Tissue - Metals Analysis Procedure

Analysis procedures were modified from those provided by Region IV; Environmental Protection Agency; Surveillance and Analysis Division; Chemical Services Branch; Athens, GA 30601.

Preparation of Samples

(1-1) Crayfish were collected from various cave sites and iced upon removal from the Cave. Samples were then frozen overnight and transported to the laboratory on ice. Samples were maintained in a freezer until analysis.

(1-2) All Crayfish were less than 5.0 grams in weight and were ashed in their entirety. Due to the small size samples were not homogenized with dry ice.

Ashing of Samples

(2-1) A 100 ml tall form Pyrex beaker was tared on a two place top loader balance. One Crayfish was added and weighed. The wet sample weight was recorded.

(2-2) 25 ml of 20% sulfuric acid was added. The sample was crushed and mixed thoroughly with a glass stirring rod. The stirring rod was rinsed with water into the ashing vessel. The vessel was covered with a Pyrex watch glass.

(2-3) Steps (2-1) and (2-2) were repeated for all samples.

(2-4) All samples were dried in an oven at 110±5°C until a charred viscous sulfuric acid/sample residue remained. (approximately 16 hours)

(2-5) Covered ashing vessels were transfered to a cold, clean muffle furnace.

(2-6) The temperature was held at 275°C for 3 hours.

(2-7) The temperature was raised at a rate of 50°C per hour until 450°C was reached.

(2-8) The 450°C temperature was maintained for 12 hours at which time the furnace was shut down and allowed to cool to 100°C.

(2-9) Ashing vessels were transferred to a desiccator until cooled to room temperature.

(2-10) Each sample was treated with 0.5 ml of water and 1 ml of concentrated nitric acid and evaporated to dryness on a warm hotplate.

(2-11) Ashing vessels were transferred to a cool muffle furnace and heated to 300°C for exactly 30 minutes.

(2-12) 0.5 ml of nitric acid and 5 ml of water were added to each vessel which were then warmed gently on a hotplate to effect dissolution of the ash.

(2-13) The contents of each ashing vessel were quantitatively transferred to a 10 ml volumetric flask, diluted to volume with water and thoroughly shaken.

Analysis of Samples

(3-1) Samples were analyzed by a Perkin-Elmer Model 363 Atomic Absorption Spectrophotometer equipped with a graphite furnace.

Concentration Calculations

(4-1) The results obtained in (3-1) were converted to concentration of each metal pollutant in the Crayfish according to the formula:

$$\text{ug/g} = \frac{\text{mg/l of constituent in prepared sample} \times \text{volume of prepared sample in ml}}{\text{weight of wet sample in g}}$$

FLORA OF THE MAMMOTH CAVE STUDY AREA

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Acanthacea: Acanthus Family
- *Justica americana* (L.) Vahl. Water-willow.
- *Ruellia strepens* L. Smooth ruellia.

Aceraceae: Maple Family
- *Acer negundo* L. Box-elder.
- *Acer rubrum* L. Red maple.
- *Acer saccharinum* L. Silver maple.
- *Acer saccharum* Marsh. Sugar maple.

Aizoaceae: Carpetweed Family
- *Mollugo verticillata* L. Carpet-weed.

Alismataceae: Water-Plantain Family
- *Sagittaria rigida* Pursh.

Amaranthaceae: Amaranth Family
- *Amaranthus retroflexus* L. Pig weed.
- *Amaranthus spinosus* L. Thorny amaranth.

Amaryllidaceae: Amaryllis Family
- *Agave virginica* L. False aloe.
- *Hymenocallis occidentalis* (Le Conte) Kunth Spider Lily.
- *Hypoxis hirsuta* (L.) Coville.
- *Narcissus pseudo-narcissus* L. Daffodil.

Anacardiaceae: Cashew Family
- *Rhus copallinum* L. Dwarf sumac.
- *Rhus radicans* L. Poison ivy.
- *Phus typhina* L. Staghorn sumac.

Annonaceae: Custard-Apple Family
- *Asimina triloba* (L.) Dunal. Pawpaw.

Apocynaceae: Dogbane Family
- *Apocynum cannabinum* L. Hemp dogbane.
- *Vinca minor* L. Periwinkle.

Aquifoliaceae: Holly Family
- *Ilex opaca* Ait. American holly.

Araceae: Arum Family
- *Arisaema triphyllum* (L.) Schott. var *triphyllum*. Jack-in-the-pulpit.
- *Arisaema triphyllum* (L.) Schott. var *pusilium* Peck. Jack-in-the-pulpit.

Araliaceae: Gingseng Family
- *Aralia racemosa* L. American spikenard.
- *Aralia spinosa* L. Hercules'-club.
- *Panax quinquefolium* L. Ginseng.

Aristolochiaceae: Birthwort Family
Aristolochia durior Hill. Dutchman's pipe.
Aristolochia serpentaria L. Virginia snake root.
Aristolochia tomentosa Sims. Pipe-vine.
Asarum canadense L. Wild ginger.

Asclepidaceae: Milkweed Family
Asclepias exaltata L. Poke milkweed.
Asclepias quadrifolia Jacq.
Asclepias syriaca L. Common milkweed.
Asclepias tuberosa L. Butterfly-weed.
Asclepias variegata L. White milkweed.
Asclepias verticillata L. Horsetail milkweed.
Gonolobus gonocarpos (Walt.) Perry.

Balsaminaceae: Touch-Me-Not Family
Impatiens biflora Walt. Spotted touch-me-not.
Impatiens pallida Nutt. Pale touch-me-not.

Berberidaceae: Barberry Family
Berberis thunbergii DC. Japanese barberry.
Caulophyllum thalictroides (L.) Michx. Blue cohosh.
Jeffersonia diphylla (L.) Pers. Twinleaf.
Podophyllum peltatum L. Mayapple.

Betulaceae: Hazel Family
Alnus maritima (Marsh.) Nutt. (*Alnus glutinosa* (L.) Gaertn.
Betula lenta L. Sweet birch.
Betula lutea Michx. f. Yellow birch.
Betula nigra L. River-birch.
Carpinus caroliniana Walt. Blue beech.
Corylus americana Walt.
Ostrya virginiana (Mill.) K. Koch. Ironwood.

Bignoniaceae: Bignonia Family
Bignonia capreolata L. Cross-vine.
Campsis radicans (L.) Sem. Trumpet-creeper.

Boraginaceae: Borage Family
Cynoglossum virginianum L. Wild comfrey.
Hackelia virginiana (L.) Johnst.
Lithospermum canescens (Michx.) Lehm. Hoary puccoon.
Lithospermum latifolium Michx. Gromwell.
Mertensia virginica (L.) Pers. Bluebells.
Myosotis verna Nutt. Forget-me-not.
Symphytum officiniale L. Comfrey.

Cactaceae: Cactus Family
Opuntia compressa (Salisb.) Macbr. Prickly pear.

Caesalpiniaceae: Pulse Family
Cassia *fasciculata* Michx. Partridge-pea.
Cassia *marilanica* L.
Cassia *nictitans* L. Wild sensitive plant.
Cercis *canadensis* L. Redbud.
Gleditsia *tricanthos* L. Honey locust.
Gymnocladus *dioica* (L.) K. Koch. Kentucky coffeetree.

Campanulaceae: Bluebell Family
Campanula *americana* L. Tall bellflower.
Triodanis *perfoliata* (L.) Niewl. Venus' looking glass.

Caprifoliaceae: Honeysuckle Family
Lonicera *japonica* Thunb. Japanese honeysuckle.
Lonicera *sempervirens* L. Trumpet honeysuckle.
Sambucus *canadensis* L. Common elder.
Symphoricarpos *orbiculatus* Moench. Coralberry.
Triosteum *perfoliatum* L. Horse-gentian.
Viburnum *acerifolium* L. Maple-leaved viburnum.
Viburnum *prunifolium* L. Blackhaw.

Caryophyllaceae: Pink Family
Arenaria *patula* Michx.
Cerastium *viscosum* L.
Dianthus *armeria* L. Deptford pink.
Paronychia *canadensis* (L.) Wood.
Paronychia *fastigata* (Raf.) Fern.
Saponaria *officinalis* L. Bouncing bet.
Silene *rotundifolia* Nutt.
Silene *stellata* (L.) Ait. f. Starry campion.
Silene *virginica* L. Firepink.
Stellaria *media* (L.) Cyrill.
Stellaria *pubera* Michx.

Celastraceae: Staff-Tree Family
Celastrus *scandens* L. Bittersweet.
Euonymus *americanus* L. Strawberry-bush.
Euonymus *atropurpuereus* Jacq. Wahoo.

Chenopodiaceae: Goosefoot Family
Chenopodium *ambrosiodes* L. Mexican tea.

Commelinaceae: Spiderwort Family
Commelina *communis* L.
Commelina *virginica* L.
Tradescantia *subaspera* Ker.
Tradescantia *virginiana* L.

Compositae: Composite Family
Achillea *millefolium* L. Yarrow.
Ambrosia *artemisiifolia* L. Common ragweed.
Antennaria *plantaginifolia* (L.) Richards.
Antennaria *solitaria* Rydb.

Anthemis cotula L. Dog-fennel.
Arctium minus (Hill) Bernh. Common burdock.
Artemisia annua L. Annual wormwood.
Aster divaricatus L.
Aster dumosus L. Bushy aster.
Aster lateriflorus (L.) Britt.
Aster linariifolius L.
Aster patens Ait.
Aster pilosus Willd.
Aster sagittifolius Willd.
Aster sericeus Vent. Silky aster.
Aster shortii Lindl.
Aster solidagineus Michx.
Aster undulatus L.
Aster vinimeus Lam.
Astranthium integrifolium (Michx.) Nutt. Daisy.
Bidens aristosa (Mich.) Britt.
Bidens bipinnata L. Spanish needles.
Bidens comosa (Gray)
Bidens polylepsis Blake.
Chrysanthemum leucanthemum L. White chrysanthemum.
Cichorium intybus L. Chichory.
Cirsium altissimum (L.) Spreng. Tall thistle.
Cirsium discolor (Muhl.) Spreng. Field thistle.
Cirsium virginianum (L.) Michx.
Coreopsis auriculata L.
Coreopsis lanciolata L.
Coreopsis major Walt.
Coreopsis pubescens Ell.
Coreopsis tripteris L. Tall tickseed.
Echinacea pallida Nutt. Pale coneflower.
Echinacea purpurea (L.) Moench. Purple coneflower.
Eclipta alba (L.) Hassk.
Elephantopus carolinianus Willd. Elephant's foot.
Erechtites hieracifolia (L.) Raf. Fireweed.
Erigeron annuus (L.) Pers. Whitetop.
Erigeron philadelphicus L.
Erigeron pulchellus Michx.
Erigeron pusillus Nutt.
Erigeron strigosus Muhl. Daisy fleabane.
Eupatorium altissimum L. Tall throughwort.
Eupatorium aromaticum L.
Eupatorium coelestinum L. Mist-flower.
Eupatorium hyssopifolium L.
Eupatorium perfoliatum L. Boneset.
Eupatorium pilosum Walt.
Eupatorium purpureum L. Joe-Pye weed.
Eupatorium rotundifolium L.
Eupatorium rugosum Houtt. White snakeroot.
Eupatorium serotinum Michx. Late boneset.
Eupatorium sessilifolium L. Upland boneset.

Galinsoga siliata (Raf.) Blake. Peruvian daisy.
Gnaphalium obtusifolium L. Sweet everlasting.
Gnaphalium purpureum L. Early cudweed.
Helenium autumnale L.
Helenium flexuosum Raf.
Helianthus divaricatus L.
Helianthus hirsutus Raf.
Helianthus microcephalus T. & G.
Helianthus mollis Lam.
Helianthus strumosus L.
Heliopsis helianthoides (L.) Sweet.
Hieracium aurantiacum L. Orange hawkweed.
Hieracium gronovii L.
Hieracium marianum Willd.
Hieracium pilosella L.
Hieracium scabrum Michx. Rough hawkweed.
Hieracium venosum L.
Krigia biflora (Walt.) Blake.
Krigia dandelion (L.) Nutt
Kuhnia eupatorioides L. False boneset.
Lactuca floridana (L.) Gaertn.
Liatris scabra (Greene) K. Schum.
Liatris scariosa (L.) Willd.
Liatris Squarrosa (L.) Michx.
Parthenium integrifolium L. American feverfew.
Polymnia canadensis L. Leaf cup.
Polymnia uvedalia L.
Prenanthes altissima L.
Prenanthes trifoliolata (Cass.) Fern.
Pyrrhopappus carolinianus (Walt.) DC.
Ratibida pinnata (Vent.) Barnh. Drooping coneflower.
Rudbeckia fulgida Ait. Orange coneflower.
Rudbeckia hirta L. Black-eyed susan.
Rudbeckia laciniata L. Goldenglow.
Rudbeckia spathulata Michx.
Rudbeckia triloba L. Brown-eyed susan.
Senecio aureus L. Golden ragwort.
Senecio obovatus Muhl.
Senecio pauperculus Michx.
Senecio smallii Britt.
Senecio visosus L.
Serinia oppositifolia (Raf.) Ktze.
Silphium integrifolium Michx. Rosin-weed.
Silphium terebinthinaceum Jacq. Prairie-dock.
Silphium trifoliatum L.
Solidago bicolor L. White goldenrod.
Solidago caesia L. Woodland goldenrod.
Solidago canadensis L. Tall goldenrod.
Solidago erecta Pursh.
Solidago flexicaulis L.
Solidago gattingeri Chapm.
Solidago juncea. Early goldenrod.

Solidago nemoralis Ait. Field goldenrod.
Solidago odora Ait.
Solidago puberula Nutt.
Solidago rugosa Mill. Roughleaved goldenrod.
Solidago sphacelata Raf.
Solidago ulmifolia Muh. Elm leaved goldenrod.
Sonchus asper (L.) Hill. Spiny sow-thistle.
Taraxacum laevigatum (Willd.) DC. Red-seeded dandelion.
Taraxcum officinale Weber. Common dandelion.
Tragopogon major Jacq. Goatsbeard.
Verbesina alternifolia (L.) Britt. Yellow ironweed.
Verbesina helianthoides Michx.
Verbesina virginica L. White crownbeard.
Vernonia altissima Nutt.

Convolvulaceae: Convolvulus Family
Convolvulus sepium L. Hedge-bindweed.
Cuscuta gronovii Willd. Dodder.
Ipomoea pandurata (L.) Mey. Wild sweet-potatoe.
Ipomoea purpurea (L.) Roth. Common morning-glory.

Cornaceae: Dogwood Family
Cornus florida L. Flowering dogweed.
Nyssa sylvatica Marsh. Black gum.

Crassulaceae: Sedum Family
Sedum pulchellum Michx.
Sedum ternatum Michx.

Cruciferae: Mustard Family
Arabis laevigata (Muhl.) Poir. Smooth rockcress.
Arabis virginica (L.) Poir.
Barbarea vulgaris R. Br. Common wintercress.
Brassica nigra (L.) Koch. Black mustard.
Capsella bursa-pastoris (L.) Medic. Shepherd's purse.
Cardamine bulbosa (Schreb.) BSP
Cardamine douglassii (Torr.) Britt.
Cardamine hirsuta L.
Cardamine parviflora L.
Cardamine pensylvanica Muh.
Dentaria heterophylla Nutt.
Dentaria laciniata Muhl. Toothwort.
Dentaria multifida Muhl.
Draba brachycarpa Nutt.
Draba verna L. Whitlow-grass.
Iodanthus pinnatifidus (Michx.) Steud.
Lepidium campestre (L.) R. Br. Field peppercress.
Lepidium ruderale L. Pepper-grass.
Lepidium virginicum L. Common peppercress.
Lesquerella globosa (Desv.) Wats.

Cyperaceae: Sedge Family
Carex cephalophora Muh.
Carex convoluta Mack.
Carex crinita Lam.
Carex eburnea Boott.
Carex pennsylvanica Lam.
Carex plantaginea Lam.
Carex platyphylla Carey.
Cyperus flavescens L.
Cyperus strigosus L.
Cyperus virens Michx.
Dulichium arundinaceum (L.) Britt.
Eleocharis obtusa (Willd.) Schultes. Blunt spike rush.
Rhynchospora corniculata (Lam.) Gray.
Scirpus rubricosus Fern.

Dioscoreaceae: Yam Family
Dioscorea quaternata (Walt.) Gmel. Wild yam.

Dipsacaceae: Teasel Family
Dipsacus sylvestris Huds. Teasel.

Ebenaceae: Ebony Family
Diospyros virginiana L. Persimmon.

Equisetaceae: Horsetail Family
Equisetum arvense L. Field horsetail.
Equisetum hyemale L. Tall scouring-rush.

Ericaceae: Health Family
Chimaphila maculata (L.) Pursh. Spotted wintergreen.
Eubotrys recurva (Buckl.) Britt.
Gaylussacia baccata (Wang.) K. Koch. Black huckleberry.
Kalmia latifolia L.
Monotropa hypopithys L. Pinesap.
Monotropa uniflora L. Indian pipe.
Oxydendrum arboreum (L.) DC. Sourwood.
Vaccinium arboreum Marsh. Farkleberry.
Vaccinium stamineum L. Deerberry.
Vaccinium uliginosum L. Bog-bilberry.
Vaccinium vacillans Torr. Hill blueberry.

Euphorbiaceae: Spurge Family
Acalypha virginica L.
Croton capitatus Michx.
Croton monanthogynus Michx.
Euphorbia corollata L. Flowering spurge.
Euphorbia maculata L. Wartweed.
Tragia cordata Michx.

Fabaceae: Pulse Family
Amphicarpa bracteata (L.) Fern.
Coronilla varia L.
Desmodium canadense (L.) DC.
Desmodium cuspidatum (Muhl.)

Desmodium glutinosum (Muhl.)
Desmodium nudiflorum (L.) DC.
Desmodium paniculatum (L.) DC.
Desmodium pauciflorum (Nutt.) DC.
Desmodium rotundifolium DC.
Lespedeza hirta (L.) Hornem.
Lespedeza intermedia (Wats.) Britt.
Lespedeza procumbens Michx. Trailing bush-clover.
Lespedeza striata (Thunb.) H. & A. Japanese clover.
Lespedeza virginica (L.) Britt. Slender bush-clover.
Medicago sativa L. Alfalfa.
Melilotus alba Desr. White sweet clover.
Melilotus officinalis (L.) Lam. Yellow sweet clover.
Psoralea psoralioides (Walt.)
Pueraria lobata (Willd.) Ohwi. Kudzu-vine
Robina hispida L. Bristly locust.
Robina pseudoacacia L. Black locust.
Strophyostyles umbellata (Muhl.)
Stylosanthes biflora (L.) BSP. Pencil-flower.
Tephrosia virginiana (L.) Pers. Goat's-rue
Trifolium agarium L. Yellow hop-clover
Trifolium hybridum L. Alsike clover.
Trifolium pratens L. Red clover.
Trifolium procumbens L. Low hop-clover.
Trifolium reflexum L. Buffalo clover.
Vicia caroliniana Walt. Carolina vetch.

Fagaceae: Beech Family
Castanea dentata (Marsh.) Borkh. American chestnut.
Fagus grandifolia Ehrh. American beech.
Quercus alba L. White oak.
Quercus bicolor Willd. Swamp white oak.
Quercus coccinea Muenchh. Scarlet oak.
Quercus falcata Michx. Southern red oak.
Quercus imbricaria Michx. Shingle oak.
Quercus macrocarpa Michx. Bur oak.
Quercus marilandica Muenchh. Blackjack oak.
Quercus muehlenbergii Engelm. Chinquapin oak.
Quercus nigra L. Water-oak.
Quercus palustris Muenchh. Pin oak.
Quercus phellos L. Willow oak.
Quercus prinus L. Chestnut oak.
Quercus rubra L. Northern red oak.
Quercus stellata Wang. Post oak.
Quercus velutina Lam. Black oak.

Fumariaceae: Poppy Family
Corydalis flavula (Raf.) DC. Pale corydalis.
Dicentra canadensis (Goldie) Walp. Squirrel corn.
Dicentra cucullaria (L.) Bernh. Dutchman's breeches.

Gentianaceae: Gentian Family
Centaurium pulchellum (Sw.) Druce. Centaury.
Gentiana andrewsii Griseb. Closed gentian.
Gentiana puberula Michx. Downy gentian.
Gentiana villosa L. Sampson-snakeroot.
Obolaria virginica L. Pennywort.
Sabatia angularis (L.) Pursh. Rose-gentian.
Swertia caroliniensis (Walt.) Ktze.

Geraniaceae: Geranium Family
Geranium carolinianum L.
Geranium dissectum L.
Geranium maculatum L. Cranesbill.
Geranium molle L.

Gramineae: Grass Family
Agrostis alba L. Redtop.
Agrostis hyemalis (Walt.) BSP. Common tickle grass
Agrostis perennans (Walt.) Tuckerm. Autumn bent grass.
Andropogon elliottii Chapm.
Andropogon gerardi Vitman Big bluestem.
Andropogon scoparius Michx. Little bluestem.
Andropogon ternarius Michx.
Andropogon virginicus L. Broom-sedge.
Aristida dichotoma Michx.
Aristida oligantha Michx.
Arundinaria gigantea (Walt.) Chapm. Cane.
Bromus commutatus Schrad. Hairy chess.
Bromus japonicus Thumb.
Bromus purgans L. Canada brome.
Dactylis glomerata L. Orchard grass.
Danthonia spictata (L.) Beauv. Oat grass.
Digitaria ischaemum (Schreb.) Muhl. Smooth crab grass.
Digitaria sanguinalis (L.) Scop. Common crab grass.
Echnochloa crusgalli (L.) Beauv. Barnyard grass.
Elymus villosus Muh. Slender wild rye.
Elymus virginicus L.
Eragrostis frankii C. A. Meyer.
Eragrostis pectinacea (Michx.) Nees.
Eragrostis spectabilis (Pursh) Steud.
Erianthus alopecuroides (L.) Ell. Plume grass.
Festuca obtusa Biehler Nodding fescue.
Glyceria striata (Lam.) Hitchc.
Hordeum pusillum Nutt. Small wild barley.
Hystrix patula Moench Bottlebrush grass.
Leersia oryzoides (L.) Sw. Cut grass.
Leptochloa filiformis (Lam.) Beauv. Sprangle-top grass.
Melica mutica Walt.
Muhlenbergia frondosa (Poir.) Fern.
Muhlenbergia mexicana (L.) Trin.
Muhlenbergia schreberi J.F. Gmel. Nimble will.
Panicum boscii Poir.
Pancium capillare L. Witch grass.

Pancium *dichotomifiorum* Michx. Fall panicum.
Panicum *gattingeri* Nash.
Panicum *latifolium* L.
Pancium *polyanthes* Schult.
Pancium *sphaerocarpon* Ell.
Panicum *stipitatum* Nash.
Panicum *virgatum* L. Switch grass.
Paspalum *pubiflorum* var. *glabrum* Vasey.
Phleum *pratense* L. Timothy.
Poa *compressa* L. Canada blue grass.
Poa *pratensis* L. Kentucky blue grass.
Setaria *glauca* (L.) Beauv. Yellow foxtail.
Sorghastrum *nutans* (L.) Nash. Indian grass.
Sorghum *halepense* (L.) Pers. Johnson grass.
Sphenopholis *intermedia* Rydb. Wedge grass.
Sporobolus *vaginiflorus* (Torr.) Wood.
Trioda *flava* (L.) Smith. Purpletop.
Uniola *latifolia* Michx. Spike grass.

Hamamelidaceae: Witch-Hazel Family
Hamamelis *virginiana* L. Witch hazel.
Liquidambar *styraciflua* L. Sweet gum.

Hippocastanacae: Buckeye Family
Aesculus *glabra* Willd. Ohio-buckeye.

Hydrophyllaceae: Waterleaf Family
Hydrophyllum *canadense* L.
Phacelia *bipinnatifida* Michx.

Hypericaceae: St. John's-Wart Family
Ascyrum *hypericoides* L. St. Andrew's cross.
Hypericum *canadense* L. Canadian St. John's-wort.
Hypericum *denticulatum* Wa.t
Hypericum *dolabriforme* Vent.
Hypericum *drummondii* (Grev. and Hook)
Hypericum *frondosum* Michx.
Hypericum *mutilum* L. Dwarf St. John's-wort.
Hypericum *perforatum* L. Common St. John's-wort.
Hypericum *punctatum* Lam. Spotted St. John's-wort.

Iridaceae: Iris Family
Belamcanda *chinensis* (L.) DC. Blackberry-lily.
Iris *cristata* Ait. Crested isis.
Sisyrinchium *albidum* Raf. Blue-eyed grass.
Sisyrinchium *augustifolium* Mill.

Juglandaceae: Walnut Family
Carya *cordiformis* (Wang.) K. Koch Bitternut hickory.
Carya *glabra* (Mill.) Sweet. Pignut hickory.
Carya *illinoensis* (Wang.) K. Koch Pecan.
Carya *laciniosa* (Michx.) Loud. Shellbark hickory.
Carya *ovalis* (Wang.) Sarg. Sweet pignut hickory.
Carya *ovata* (Mill.) Sweet. Shagbark hickory.

Carya tomentosa (Poir.) Nutt. Mockernut.
Juglans cinerea L. Butternut.
Juglans nigra L. Black walnut.

Juncaceae: Rush Family
Juncus acuminatus Michx.
Luzula echinata (Small) F. J. Herm.

Labiatae: Mint Family
Blephilia ciliata (L.) Benth. Wood mint.
Collinsonia canadensis L. Richweed.
Glecoma hederacea L. Ground-ivy.
Hedeoma pulegioides (L.) Pers. American pennyroyal.
Isanthus brachiatus (L.) BSP. False pennyroyal.
Lycopus americanus Muh. Water horehound.
Lycopus uniflorus Michx.
Lycopus virginicus L.
Meehania cordata (Nutt.) Britt.
Mentha piperita L. Peppermint.
Monarda bradurniana Beck.
Monarda clinopodia L.
Monarda fistulosa L. Wild bergamot.
Monarda russeliana Sims.
Perilla frutescens (L.) Britt. Beefsteak plant.
Physostegia virginiana (L.) Benth. False dragonhead.
Prunella vulgaris L.
Pycnanthemum flexuosum (Walt.) BSP. Mountain Mint.
Pycnanthemum incanum (L.) Michx.
Salvia lyrata L. Cancer-weed.
Scutellaria elliptica Muh. Hariy skullcap
Scutellaria incana Biehler Downy skullcap.
Scutellaria lateriflora L.
Scutellaria nervosa Pursh.
Scutellaria parvula Michx.
Synandra hispidula (Michx.) Baill.
Teucrium canadense L. Wood-sage.
Trichostema dichotomum L. Bluecurls.
Trichostema setaceum Houtt.

Lauraceae: Laurel Family
Lindera benzoin (L.) Blume. Spice bush.
Sassafras albidum (Nutt.) Nees Sassafras.

Lemnaceae: Duckweed Family
Spirodela polyrhiza (L.) Schleid. Duckweed

Liliaceae: Lily Family
Allium canadense L. Wild garlic.
Allium tricoccum Ait. Wild leek.
Asparagus officinalis L. Garden asparagus.
Chamaelirium luteum (L.) Gray. Blazing star.
Erythronium albidum Nutt. Trout lily.

Erythronium americanum Ker. Trout lily.
Hemerocallis fulva L. Day Lily.
Lilium canadense L. Wild yellow lily.
Lilium philadelphicum L. Wood lily.
Medeola virginiana L. Indian cucumber-root.
Nothoscordum bivalve (L.) Britt. False garlic.
Ornithogalum umbellatum L. Star-of-Bethlehem.
Polygonatum biflorum (Walt.) Ell. Small Solomon's-seal.
Smilacina racemosa (L.) Desf. False Solomon's-seal.
Smilacina stellata (L.) Desf.
Smilax bona-nox L. Fringed greenbrier.
Smilax ecirrhata (Engelm.) S. Wats.
Smilax glauca Walt. Sawbrier.
Smilax herbacea L. Carrion flower.
Smilax rotundifolia L.
Smilax tamnoides Fern.
Trillium gleasoni Fern.
Trillium recurvatum Beck Purple trillium.
Trillium sessile L.
Uvularia perfoliata L.
Uvularia sessilifolia L.

Linaceae: Flax Family
Linum medium (Planch.) Britt.
Linum virginianum L.

Lobeliaceae: Blue Bell Family
Lobelia cardinalis L. Cardinal flower.
Lobelia inflata L. Indian-tobacco.
Lobelia puberula Michx. Downy lobelia.
Lobelia spicata Lam. Spiked lobelia.
Lobelia syphilitica L. Blue cardinal flower.

Lycopodiaceae: Club-Moss Family
Lycopodium lucidulum Michx.

Lythraceae: Loosestrife Family
Cuphea petiolata (L.) Koehne Blue waxweed.

Magnoliaceae: Magnolia Family
Liriodendron tulipifera L. Tuliptree.
Magnolia acuminata L. Cucumber tree.
Magnolia macrophylla Michx. Bigleaf magnolia.
Magnolia tripetala L. Umbrella magnolia.

Malvaceae: Mallow Family
Hibiscus militaris Cav. Rose-mallow.
Hibiscus moscheutos L. Rose-mallow.
Sida spinosa L.

Melastomataceae: Melastoma Family
Rhexia mariana L.
Rhexia virginica L.

Menispermaceae: Moonseed Family
Menispermum canadense L. Moonseed.

Moraceae: Mulberry Family
Maclura pomifera (Raf.) Schneid. Osage-orange.
Morus rubra L. Red mulberry.

Oleaceae: Olive Family
Fraxinus americana L. American ash.
Fraxinus nigra Marsh. Black ash.
Fraxinus pennsylvanica Marsh. Green ash.
Fraxinus quadrangulata Michx. Blue ash.

Onagraceae: Evening-Primrose Family
Gura filipes Spach.
Ludwigia alternifolia L. Seed-box.
Ludwigia palustris (L.) Ell. False loosestrife.
Oenothera fruiticosa L. Sundrops.
Oenothera rhombipetala Nutt.
Oenothera tetragona Roth. Sundrops.

Ophioglossaceae: Adder's-Tongue Family
Botrychium dissectum Spreng. Grape fern.
Botrychium virginianum (L.) Sw. Rattlesnake fern.
Ophioglossum engelmanni Prantl. Adder's-tongue.

Orchidaceae: Orchis Family
Apelctrum hyemale (Muhl.) Torr. Puttyroot
Corallorhiza odontorhiza (Willd.) Nutt. Later coralroot.
Corallorhiza wisteriana Conrad. Wister's coralroot.
Cypripedium calceolus L. Yellow lady-slipper.
Goodyera pubescens (Willd.) R. Br. Rattlesnake-plantain.
Hexalectris spicata (Walt.) Barnh. Crested coralroot.
Liparis lilifolia (L.) L. C. Richard Twayblade.
Orchis spectabilis L. Showy orchis.
Spiranthes cernua (L.) Rich. Nodding ladies' tresses.
Spiranthes ovalis Lindl.
Spiranthes tuberosa Raf.
Spiranthes vernalis Engelm. & Gray
Tipularia discolor (Pursh) Nutt. Crane-fly orchid.

Orobanchaceae: Broom-Rape Family
Conopholis americana (L.) Wallr. Squaw-root.
Epifagus virginiana (L.) Bart. Beech-drops.

Osmundaceae: Flowering Fern Family
Osmunda cinnamomea L. Cinnamon fern.
Osmunda regalis L. Royal fern.

Oxalidaceae: Wood-Sorrel Family
Oxalis grandis Small.
Oxalis stricta L. Upright yellow wood-sorrel.
Oxalis violacea L. Violet wood-sorrel.

Papaveraceae: Poppy Family
Sanguinaria canadensis L. Bloodroot.
Stylophorum diphyllum (Michx.) Nutt. Celandine poppy.

Passifloraceae: Passion-Flower Family
Passiflora incarnata L. Maypops.
Passiflora lutea L.

Phytolaccacea: Pokeweed Family
Phytolacca americana L. Pokeweed.

Pinaceae: Pine Family
Juniperus virginiana L. Eastern red cedar.
Pinus echinata Mill. Shortleaf pine.
Pinus strobus L. Eastern white pine.
Pinus virginiana Mill. Virginia pine.
Tsuga canadensis (L.) Carr. Eastern hemlock.

Plantaginaceae: Plantain Family
Plantago aristata Michx. Buckhorn.
Plantago lanceolata L. English plantain.
Plantago media L. Eurasia.
Plantago rugelii Decne. Common plantain.
Plantago virginica L.

Platanaceae: Plane-Tree Family
Platanus occidentalis L. Sycamore.

Polemoniaceae: Plemonium Family
Phlox amoena Sims.
Phlox bifida Beck. Sand phlox.
Phlox divaricata L. Blue phlox.
Phlox glaberrima L. Smooth phlox.
Phlox maculata L. Sweet-william phlox.
Phlox paniculata L. Garden phlox.
Polemonium reptans L.

Polygalaceae: Milkwart Family
Polygala sanguinea L.
Polygala verticillata L.

Polygonaceae: Buckwheat Family
Polygonum convolvulus L. Black bindweed.
Polygonum cristatum Engelm. & Gray
Polygonum douglasii Greene.
Polygonum persicaria L. Lady's thumb.
Polygonum punctatum Ell. Water smartweed.
Polygonum scandens L. False buckwheat.
Polygonum virginianum L. Virginia knotweed.
Rumex acetosella L. Red sorrel.
Rumex crispus L. Curley dock.

Polypodiaceae: Fern Family

- *Adiantum pedatum* L. Maidenhair fern.
- *Asplenium montanum* Willd. Mountain spleenwort.
- *Asplenium pinnatifidum* Nutt.
- *Asplenium platyneuron* (L.) Oakes Ebony spleenwort.
- *Asplenium resiliens* Kunze. Black spleenwort.
- *Asplenium trichomanes* L. Maidenhair spleenwort.
- *Asplenium trudelli* Wherry.
- *Athyrium filix-femina* L. Lady fern.
- *Athyrium pycnocarpon* (Spreng.) Tidest. Glade fern.
- *Athyrium thelypterioides* (Michx.) Desv. Silvery spleenwort.
- *Camptosorus rhizophyllus* (L.) Link Walking fern.
- *Cheilanthes lanosa* (Michx.) D.C. Eat. Lip fern.
- *Cystopteris biulifera* (L.) Bernh. Bladder fern.
- *Cystopteris fragilis* (L.) Bernh.
- *Dennstaedtia punctilobula* (Michx.) Moore Hayscented fern.
- *Dryopteris goldiana* (Hook.) Gray Goldie's fern.
- *Dryopteris marginalis* (L.) Gray Marginal wood fern.
- *Dryopteris noveboracenis* (L.) Gray New York fern.
- *Dryopteris spinulosa* (O.F. Muell.) Watt. Spinulose wood fern.
- *Onoclea sensibilis* L. Sensitive fern.
- *Pellaea atropurpurea* (L.) Link Cliff-brake.
- *Polypodium polypodioides* (L.) Watt. Resurrection fern.
- *Polypodium virginianum* L. (*P. vulgare* L. in Gleason and Cronquist, 1963).
- *Polystichum acrostichoides* (Michx.) Schott. Christmas fern.
- *Pteridium aquilinum* (L.) Kuhn Bracken fern.
- *Thelypteris hexagonoptera* (Michx.) Weatherby. Broad beech-fern.
- *Woodsia Obtusa* (Spreng.) Torr. Cliff fern.

Portulaceae: Purslane Family

- *Claytonia virginica* L. Spring beauty.
- *Portulaca oleracea* L. Purslane.

Primulaceae: Primerose Family

- *Anagallis arvensis* L. Pimpernel.
- *Dodecatheon meadia* L. Shooting-star.
- *Lysimachia lanceolata* Walt. Loosestrife.
- *Lysimachia quadrifolia* L. Whorled loosestrife.
- *Samolus parviflorus* Raf. Brookweed.

Ranunculaceae: Crowfoot Family

- *Actaea pachypoda* Ell. White baneberry.
- *Anemone quinquefolia* L. Eastern N.A. Mixed woods.
- *Anemone virginiana* L. Tall anemone.
- *Anemonella thalictroides* (L.) Spach. Rue anemone.
- *Aquilegia canadensis* L. Columbine.
- *Clematis glaucophylla* Small Leather flower.
- *Clematis viorna* L. Leather flower.
- *Delphinium tricorne* Michx. Dwarf larkspur.
- *Hepatica acutiloba* DC.
- *Hydrastis canadensis* L. Goldenseal.
- *Isopyrum biternatum* (Raf.) T. & G. False rue anemone.

Ranunculus abortivus L. Small-flowered crowfoot.
Ranunculus fascicularis Muh. Tufted buttercup.
Ranunculus hispidus Michx. Bristly buttercup.
Ranunculus recurvatus Poir.
Ranunculus sardous Crantz.
Ranunculus septentrionalis Poir. Marsh buttercup.
Thalictrum dioicum L. Early meadow-rue.
Thalictrum polygamum Muhl.
Thalictrum revolutum DC. Waxy meadow-rue.

Rhamnaceae: Buckthorn Family
Ceanothus americanus L. New Jersey tea.
Rhamnus carolinianus Walt. Carolina buckthorn.

Rosaceae: Rose Family
Agrimonia parviflora Ait.
Agrimonia pubescens Wallr.
Agrimonia rostellata Wallr.
Amelanchier arborea (Michx. F.) fern.
Aruncus dioicus (Walt.) Fern.
Duchesnea indica (Andr.) Focke. Indian strawberry.
Fragaria virginiana Duch. Wild strawberry.
Geum vernum (Raf.) T. & G. Spring avens.
Geum virginianum L.
Gillenia stipulata (Muhl.) Trel. Indian physic.
Physocarpus opulifolius (L.) Maxim. Ninebark.
Potentilla recta L.
Potentilla simplex Michx. Common cinquefoil.
Prunus americana Marsh. Wild plum.
Prunus serotina Ehrh. Wild black cherry.
Rosa carolina L. Carolina rose.
Rosa setigera Michx. Prairie-rose.
Rosa virginiana Mill. (doubtful identification)
Rubus flagellaris Willd. Dewberry.
Rubus occidentalis L. Black raspberry.
Rubus pensylvanicus Poir.
Waldsteinia fragarioides (Michx.) Tratt. Barren strawberry.

Rubiaceae: Madder Family
Cephalanthus occidentalis L. Buttonbush.
Diodia teres Walt. Rough buttonweed.
Diodia virginiana L.
Galium asprellum Michx. Rough bedstraw.
Galium circaezans Michx.
Galium obtusum Bigel.
Galium triflorum Michx. Sweet-scented bedstraw.
Houstonia caerulea L.
Houstonia lanceolata (Poir.)
Houstonia longifolia Gaertn.
Houstonia purpurea L.
Houstonia pusilla Schoepf.
Mitchella repens L. Partridge-berry.

Rutaceae: Rue Family
Ptelea trifoliata L. Hop-tree.

Salicaceae: Willow Family
Populus alba L. White poplar.
Salix gracilis Fern.
Salix humilis Marsh. Upland-willow.
Salix interior Rowlee Sandbar-willow.
Salix nigra L.
Salix sericea Marsh. Silky willow.

Santalaceae: Sandalwood Family
Comandra richardsiana Fern. Bastard toad-flax.

Saururaceae: Lizards-Tail Family
Saururus cernuus L. Lizard-tail.

Saxifragaceae: Faxifrage Family
Astilbe biternata (Vent.) Britt. False goat's beard.
Boykinia aconitifolia Nutt. Appalachian Mts.
Heuchera americana L.
Heuchera parviflora Bartl.
Heuchera villosa Michx.
Hydrangea aborescens L.
Mitella diphylla L. Bishop's cap.
Penthorum sedoides L. Dutch stonecrop.
Saxifraga virginiensis Michx.
Tiarella cordifolia L. Foam-flower.

Scrophulariaceae: Figwort Family
Aureolaria flava (L.) Farw.
Aureolaria virginica (L.) Pennell.
Buchnera americana L. Bluehearts.
Chelone obliqua L.
Gerardia tenufolia Vahl.
Leucospora multifida (Michx.) Nutt.
Linaria vulgaris Hill. Butter-and-eggs.
Minulus alatus Ait.
Paulownia tomentosa (Thumb.) Steud. Empress-tree.
Pedicularis canadensis L.
Penstemon calycosus Small.
Penstemon pallidus Small.
Scrophularia marilandica L.
Seymeria macrophylla Nutt.
Verbascum blattaria L. Moth-mullein.
Verbascum thapsus L.
Veronica arvensis L.
Veronicastrum virginicum (L.) Farw. Culver's root.

Simarubaceae: Quassia Family
Ailanthus altissima (Mill.) Swingle. Tree-of-heaven.

Solanaceae: Nightshade Family
Datura stramonium L. Jimson-weed.
Physalis heterophylla Nees.
Physalis longfolia Nutt.
Solanum carolinense L. Horse-nettle.
Solanum nigrum L. Black nightshade.

Sparganiaceae: Bur-Reed Family
Sparganium androcladum (Engelm.) Morong.

Staphyleaceae: Bladdernut Family
Staphylea trifolia L. Badder-nut.

Tiliaceae: Liden Family
Bilia americana L. Basswood.

Typhaceae: Cat-Tail Family
Typha latifolia L. Cat-tail

Ulmaceae: Elm Family
Celtis occidentalis L. Hackberry.
Planera aquatica (Walt.) J. F. Gmel. Planer-tree.
Ulmus alata Michx. Winged elm.
Ulmus americana L. American elm.
Ulmus rubra Muhl. Slippery elm.
Ulmus thomasi Sarg. Rock elm.

Umbelliferae: Parsley Family
Angelica venenosa (Greenway) Fern.
Crypotaenia canadensis (L.) DC. Honewort.
Daucus carota L. Queen Ann's lace.
Erigenia bulbosa (Michx.) Nutt. Salt and pepper.
Eryngium yuccifolium Michx. Rattlesnake-master.
Osmorhiza claytoni (Michx.) Clarke.
Oxypolis rigidior (L.) C. and R.
Sanicula canadensis L. Black snakeroot.
Sanicula marilandica L.
Taenidia integerrima (L.) Drude.
Thaspium pinnatifidum (Buckl.) Gray Meadow-parsnip.
Zizia aptera (Gray) Fern.

Urticaceae: Nettle Family
Boehmeria cylindrica (L.) Sw. False nettle.
Laportea canadensis (L.) Wedd. Wood-nettle.
Parietaria pensylvanica Muhl. Pellitory.
Pilea pumila (L.) Gray Clearweed.

Valerianaceae: Valerian Family
Valeriana pauciflora Michx.

Verbenaceae: Vervain Family
Verbena canadensis (L.) Britt.
Verbena simplex Lehm.
Verbena stricta Vent.
Verbena urticifolia L.

Violaceae: Violet Family
Hybanthus concolor (T.F. Forst.) Spreng. Green violet.
Viola affinis LeConte.
Viola conspersa Reichenb. American dog-violet.
Viola cucullata Ait. Blue marsh-violt.
Viola eriocarpa Schw. Smooth yellow violet.
Viola hirsutula Brainerd.
Viola incognita Brainerd.
Viola kitaibeliana Fern.
Viola lanceolata L.
Viola papilionacea Pursh. Meadow-violet.
Viola pedata L. Bird-foot violet.
Viola pensylvanica Michx.
Viola sagittata Ait. Arrowleaf violet.
Viola sororia Willd. Woolly blue violet.
Viola striata Ait.
Viola triloba Schwein.

Vitaceae: Vine Family
Parthenocissus quinquefolia (L.) Planch. Virginia creeper.
Vitis aestivalis Michx. Summer-grape.
Vitis cinerea Engelm.
Vitis vulpina L. Forest-grape.

WILDLIFE OF MAMMOTH CAVE STUDY AREA

WILDLIFE OF MAMMOTH CAVE STUDY AREA (BERRY, 1969)

Salamander:

Necturus maculosus. Waterdog.
Cryptobrahchus alleganinesis. Hellbender.
Diemictylus viridescens viridescens. Red spotted newt.
Ambystoma jeffersonianum. Jefferson salamander.
Ambystoma maculatum. Spotted salamander.
Ambystoma opacum. Marbled salamander.
Ambystoma tigrinum. Toger salamander.
Plethodon dorsalis. Zigzag salamander.
Plethodon glutinosus. Slimy salamander.
Pseudotriton montanus montanus. Eastern mud salamander.
Pseudotriton ruber ruber. Northern red salamander.
Eurycea bislineata bisleneata. Northern two-lined salamander.
Eurycea longicauda. Lon-tailed salamander.
Eurycea luciferga. Cave salamander.
Desmognathus fuscus fuscus. Northern dusky salamander.
Ambystoma texanum. Small mouth salamander.

Toads:

Scophiopus holbrookii holbrookii. Eastern spadefoot toad.
Bufo americanus. American toad.
Bufo woodhousei fowleri. Fowler's toad.

Frogs:

Acris gryllius gryllus. Southern cricket frog.
Pseudacris brachyphona. Mountain chorus frog.
Hyla crucifer. Spring peeper.
Hyla versicolor. Gray treefrog.
Rana catesbeiana. Bull frog.
Rana clamitans elanota. Green frog.
Rana palustris. Pickered frog.
Rana pipiens. Leopard frog.
Rana sylvatica. Wood frog.
Gastrophryne carolinensis. Eastern narrow-mouthed toad.

Lizards:

Sceloporus undulatus. Fence lizard.
Ophisaurus ventralis. Eastern glass lizard.
Opemidophorus sexlineatus. Six-lined racerunner.
Lygosoma laterale. Ground skink.
Eumeces anthracinus. Coal skink.
Eumeces fasciatus. Blue tailed skink.
Eumeces laticeps. Broad-headed skink.

Turtles:

Sternotherus odoratus. Stinkpot turtle.
Chelydra serpentina. Snapping turtle.
Terrapene carolina carolina. Eastern box turtle.
Graptemys geographica. Map turtle.
Pseydemys concinna heirohlyphia. Slider.

Pseudemys scripta elegans. Red eared turtle.
Trinonyx muticus. Smooth softshell turtle.
Trionyx spinifer spinifer. Eastern spiny softshell turtle.

Snakes:
Carphophis amoena amoena. Worm snake.
Carphophis amoenus helenae. Worm snake.
Piadophis punctatus edwardsi. Northern ringneck.
Heterodon platyrhinos. Hognose snake.
Opheodrys aestivies. Rough green snake.
Coluber constrictor constrictor. Northern black river snake.
Elaphe guttata guttata. Corn snake.
Elaphe obsoleta spiloides. Gray rat snake.
Pituophis melanolucus melanoleucus. Northern pine snake.
Lampropeltis calligaster calligaster. Prairie king snake.
Lampropeltis doliata doliata. Scarlet king.
Lampropeltis getulus niger. Black king snake.
Lampropeltis doliata triangulum. Easter silk snake.
Cemophora coccinea. Scarlet snake.
Natrix sipedon sipedon. Northern water snake.
Storeria dekayi dekayi. Northern brown snake.
Storeria occipitomaculata. Red-bellied snake.
Thamnophis sirtalis sirtalis. Eastern garter snake.
Thamnophis butleri. Butler's garter snake.
Thamnophis sauritus sauritus. Eastern ribbon snake.
Tantilla coronata coronata. Southeastern crowned snake.
Agkistrodon contortris mokeson. Northern copperhead.
Crotalus horridus horridus. Timber rattler.

Mammals:
Didelphis marsupialis. Opossum.
Scalapus aquaticus. Eastern mole.
Myotis lucifugus. Little brown bat.
Myotis grisecens. Grat bat.
Myotis keeni. Keen or sharp-eared bat.
Myotis sodalis. Indiana bat.
Myotis subalatus. Small footed bat.
Lasionycteris noctivagans. Silver haired bat.
Pipisterllus sybflavus. Eastern pipistrel bat.
Eptesicus fuscus. Big brown bat.
Lasiurus borealis. Red bat.
Lasirusu cinereus. Hoary bat.
Mycticeusi humeralis. Evening bats.
Plecotus rafinesquei. Eastern big eared or rabbit eared bat.
Procyon lotor. Raccoon.
Mustela frenate. Longtail weasel.
Mustela vison. Mink.
Spilogale putorius. Spotted skunk.
Mephitis mephitis. Striped skunk.
Vulves falva. Red fox.
Vrocyon anereoargenteus. Gray fox.
Marmota monax. Woodchuck.
Tamias striatus. Eastern chipmunk.
Sciurus carolinensis. Eastern gray squirrel.
Sciurus niger. Eastern fox squirrel.

Glaucomys volans. Southern flying squirrel.
Caster canadensis. Beaver.
Peromyscus leucopus. White footed mouse.
Peromyscus maniculatus. Deer mouse.
Reithrodontomys humulis. Eastern harvest mouse.
Peromyscus nuttalli. Golden mouse.
Neotoma floridana. Eastern woodrat.
Microtus pennsylvanicus. Meadow vole.
Pitymus pinetorum. Pine vole.
Ondatra zibetheca. Muskrat.
Rattus norvegicus. Norway rat.
Mus mucsulus. House mouse.
Sylvilagus floridanus. Eastern cottontail.
Odocoileus virginianus. Virginia white-tail deer.
Blarina brevicauda. Short tail shrew.
Cyptotis parva. Least shrew.
Sorex fumeus. Smoky shrew.
Lynx rufus. Bobcat.

BIRD SPECIES LIST FOR THE MAMMOTH CAVE STUDY AREA
(Modified from Wilson, 1968)

Bird Species Within Mammoth Cave National Park

		Abundance		
		Rare	Common	Abundant
All-Year Residents				
Bluebird, Eastern	*Sialia sialis*			x
Bobwhite	*Colinus virginianus*		x	
Cardinal	*Richmondena cardinalis*			x
Chickadee, Carolina	*Parus carolinensis*			x
Crow, Common	*Corvus brachyrhynchos*	x	x	
Dove, Mourning	*Zehaidura macroura*	x	x	
Flicker, Yellow-shafted	*Coloptes auratus*			x
Goldfinch, American	*Spinus tristis*			x
Hawk, Cooper's	*Accipiter cooperii*	x		
Hawk, Red-shouldered	*Buteo lineatus*	x		
Hawk, Red-tailed	*Buteo jamaicensis*		x	
Hawk, Sharp-shinned	*Accipiter striatus*	x		
Hawk, Sparrow	*Falco sparverius*	x		
Jay, Blue	*Cyanocitta cristata*			x
Killdeer	*Charadrius vociferus*	x		
Kingfisher, Belted	*Megaceryie alcyon*	x		
Lark, Horned	*Eremophila alpestris*	x		
Meadowlark, Eastern	*Sturnella magna*	x		
Mockingbird	*Mimus polyglottus*	x	x	
Nuthatch, White-breasted	*Sitta carolinensis*		x	
Owl, Barred	*Strix varig*		x	
Owl, Horned	*Bubo virginianus*	x		
Owl, Screech	*Otus asio*	x		
Phoebe, Eastern	*Sayornis phoebe*	x	x	
Robin	*Turdus, migratorius*		x	x
Shrike, Loggerhead	*Lanius ludovicianus*	x		
Sparrow, Field	*Spizella pusilla*		x	
Sparrow, House	*Passer domesticus*	x	x	
Starling	*Sturnus vulgaris*	x	x	
Titmouse, Tufted	*Parus bicolor*			x
Turkey	*Meleagris gallopavo*	x		
Towhee, Rufous-sided	*Pipilo erythrophthalmus*			x
Vulture, Black	*Coragyps atratus*	x	x	
Vulture, Turkey	*Cathartes aurg*	x	x	
Woodcock, American	*Philohela minor*	x		
Woodpecker, Downy	*Dendrocopus pubescens*			x
Woodpecker, Hairy	*Dendrocopus villosus*		x	
Woodpecker, Pileated	*Dryocopus pileatus*		x	
Woodpecker, Red-bellied	*Centurus carolinus*			x
Woodpecker, Red-headed	*Melanerpes erythrocephalus*	x		
Wren, Bewick's	*Thryomanes bewickii*	x		
Wren, Carolina	*Thryothorus indovicianus*		x	x

BIRD SPECIES LIST FOR THE MAMMOTH CAVE EIS

		Abundance		
		Rare	Common	Abundant
Summer Residents				
Blackbird, Red-winged	*Agelaius phoeniceus*	x	x	
Bunting, Indigo	*Passerina cyanea*			x
Catbird	*Dumetella carolinensis*			x
Chat, Yellow-breasted	*Icteria virens*			x
Chuck-will's-widow	*Caprimulgus carolinensis*	x		
Cowbird, Brown-headed	*Molothrus ater*		x	x
Cuckoo, Yellow-billed	*Coccyzus americanus*			x
Dickcissel	*Spiza americana*	x		
Duck, Wood	*Aix sponsa*		x	
Flycatcher, Acadian	*Empidonax virescens*			x
Flycatcher, Great Crested	*Myiarchus crinitus*			x
Gnatcatcher, Blue-gray	*Polioptila caerulea*			x
Grackle, Common	*Quiscalus quiscula*	x	x	
Hawk, Broad-winged	*Buteo platypterus*	x		
Heron, Green	*Butorides virescens*	x	x	
Hummingbird, Ruby-throated	*Archilochus colubris*			x
Kingbird, Eastern	*Tyrannus tyrannus*	x		
Martin, Purple	*Progne subis*	x		
Nighthawk, Common	*Chordeiles minor*	x		
Oriole, Baltimore	*Icterus galbula*	x		
Oriole, Orchard	*Icterus spurius*	x	x	
Ovenbird	*Seiurus aurocupillus*			x
Pewee, Eastern Wood	*Contopus virens*			x
Redstart American	*Setophaga ruticilla*			x
Sparrow, Bachman's	*Aimophila aestivalis*	x		
Sparrow, Chipping	*Spizella passerina*			x
Sparrow, Grasshopper	*Ammodramus savannorum*	x		
Sparrow, Lark	*Chondestes grammacus*	x		
Swallow, Barn	*Hirundo rustica*	x		
Swallon, Rough-winged	*Steligidopteryx ruficollis*		x	
Swift, Chimney	*Chaetura pelagica*	x		
Tanager, Scarlet	*Piranga olivacea*			x
Tanager, Summer	*Piranga rubra*			x
Thrush, Wood	*Hylocichla mustelina*			x
Thrasher, Brown	*Toxostoma rufum*		x	
Vireo, Rey-eyed	*Vireo olivaceus*			x
Vireo, Warbling	*Vireo gilvus*	x		
Vireo, White-eyed	*Vireo ariseus*			x
Vireo, Yellow-throated	*Vireo flavifrons*			x
Warbler, Black-and-white	*Mniotilta varia*			x
Warbler, Blue-winged	*Vermivora pinus*	x		
Warbler, Cerulean	*Pendroica cerula*			x
Warbler, Hooded	*Wilsonia citrina*			x
Warbler, Kentucky	*Oporornis formosus*			x
Warbler, Parula	*Parula americana*	x	x	
Warbler, Prairie	*Pendroica discolor*		x	x

BIRD SPECIES LIST FOR THE MAMMOTH CAVE EIS

			Abundance	
		Rare	Common	Abundant
Warbler, Prothonotary	Protonotaria citrea			x
Warbler, Worm-eating	Helmitheros vermivorus		x	
Warbler, Yellow	Dendroica petechia		x	x
Warbler, Yellow-throated	Dendroica dominica			x
Waterthrush, Louisiana	Seiurus motacilla			x
Whip-poor-will	Caprimulgus vociferus			x
Yellowthroat	Geothlypis thrichas			x
Winter Residents				
Blackbird, Rusty	Euphagus carolinus	x	x	
Creeper, Brown	Certhia familiaris	x	x	
Duck, Black	Anas rubripes	x		
Finch, Purple	Carpodacus purpurens			x
Grosbeak, Evening	Hesperiphona vespertina	x		
Hawk, Marsh	Circus cyaneus	x		
Hawk, Rough-legged	Buteo lagopus	x		
Junco, Slate-colored	Junco hyemalis			x
Kinglet, Golden-crowned	Regulus sutrapa		x	
Kinglet, Ruby-crowned	Regulus calendula	x	x	
Mallard	Anas platyrhynchos	x	x	
Nuthatch, Red-breasted	Sitta canadensis	x		
Sapsucker, Yellow-bellied	Sphyrapicus varius		x	
Siskin, Pine	Spinus pinus	x	x	
Snipe, Collom	Capella gallinayo	x		
Sparrow, Fox	Passerella iliaca	x		
Sparrow, Savannah	Passerculus sandwichensis	x		
Sparrow, Song	Melospiza melodia		x	
Sparrow, Swamp	Melospiza georgiana	x		
Sparrow, Tree	Spizella asbosea	x	x	
Sparrow, Vesper	Pooecetes gramineus	x		
Sparrow, White-crowned	Zonotrichia leucophrys	x		
Sparrow, White-throated	Zonotrichia albicollis		x	x
Thrush, Hermit	Hylocichla guttata		x	
Warbler, Myrtle	Dendroica coronata			x
Waxwing, Cedar	Bombycilla cedrorum			x
Wren, Winter	Troglodytes troglodytes	x	x	
Transients				
Bittern, American	Botaurus lentiginosus	x		
Bittern, Least	Ixobrychus exiles	x		
Bufflehead	Bucephala albeola	x		
Canvasback	Aythya valisineria	x		
Coot, American	Fulica americana	x		
Cormorant, Double-crested	Phalacrocorax aunitus	x		
Crane, Sandhill	Grus canadensis	x		
Cuckoo, Black-billed	Coccygus erythrocephalus		x	
Duck, Redhead	Aythya americana	x		
Duck, Ring-necked	Aythya, collaris	x		

BIRD SPECIES LIST FOR THE MAMMOTH CAVE EIS

		Abundance		
		Rare	Common	Abundant
Eagle, Bald	*Haliaeetus leucocephalus*	x		
Flycatcher, Least	*Empidonax minima*	x		
Flycatcher, Olive-sided	*Nuttallornis borealis*	x		
Flycatcher, Traill's	*Empidonax traillii*	x		
Flycatcher, Yellow-bellied	*Empdonax flaviventris*	x		
Gallinule, Common	*Gallinula chloropus*	x		
Goose, Blue	*Chen caerulescens*	x	x	
Goose, Canada	*Branta canadensis*	x	x	
Goose, Snow	*Chen hyperborea*	x		
Grebe, Red-necked	*Podiceps grisegena*	x		
Grosbeak, blue	*Guiraca caerulea*	x		
Grosbeak, Rose-breasted	*Pheucticus ludovicianus*		x	
Hawk, Pigeon	*Falco columbarius*	x		
Heron, Great Blue	*Ardea herodias*	x		
Heron, Black-crowned Night	*Nycticorax nycticorax*	x		
Heron, Little Blue	*Florida caerulea*	x		
Merganser, Common	*Mergus merganser*	x		
Osprey	*Pandion haliaetus*	x		
Owl, Snowy	*Nyctea scandiaca*	x		
Pintail	*Anas acuta*	x		
Plover, Upland	*Bartramia longicanda*	x		
Pipit, Water	*Anthus spinoletta*	x		
Rail, King	*Rallus elegans*	x		
Rail, Virginia	*Rallus limicola*	x		
Redpoll, Common	*Acanthus flammea*	x		
Sandpiper, Least	*Eroliaminutilla*	x		
Sandpiper, Solitary	*Tringa solitaria*		x	
Sandpiper, Spotted	*Actitis macularia*		x	
Scaup, Lesser	*Aythya affinis*	x		
Shoveler	*Spatula clypeata*	x		
Sora	*Porzana carolina*	x		
Swallow, Bank	*Riparia riparia*	x		
Swallow, Cliff	*Petrouhelidon pyrrhonata*	x		
Swallow, Tree	*Iridoproche bicolor*	x		
Teal, Blue-winged	*Anas discors*	x		
Teal, Green-winged	*Anas carolinensis*	x		
Tern, Least	*Sterna albitrons*	x		
Thrush, Gray-cheeked	*Hylocichla minima*			x
Thrush, Swainson's	*Hylocichla ustulata*			x
Veery	*Hylocichla fuscescens*	x	x	
Vireo, Bell's	*Vireo bellii*	x		
Vireo, Philadelphia	*Vireo philadelphicus*	x		
Vireo, Solitary	*Vireo solitarius*	x		
Warbler, Bay-breasted	*Dendroica castanea*	x		

BIRD SPECIES LIST FOR THE MAMMOTH CAVE EIS

		Abundance		
		Rare	Common	Abundant
Warbler, Blackburnian	Dendroica fusca		x	
Warbler, Blackpoll	Dendroica striata			x
Warbler, Black-throated Blue	Dendroica caerulescens	x		
Warbler, Black-throated Green	Denroica virens			x
Warbler, Canada	Wilsonia canadensis	x		
Warbler, Cape May	Denroica tigrina	x	x	
Warbler, Chestnut-sided	Denroica pennsylvanica		x	
Warbler, Connecticut	Oporornis agilis	x		
Warbler, Golden-winged	Vermivora chrysoptera	x		
Warbler, Magnolia	Dendroica magnolia			x
Warbler, Mourning	Oporonis philadelphia	x		
Warbler, Nashville	Vermivora ruficapilla		x	
Warbler, Orange-crowned	Vermivora celata	x		
Warbler, Palm	Dendroica palmarum			x
Warbler, Pine	Dendroica pinus	x		
Warbler, Swainson's	Limnothlypis swainsonii	x		
Warbler, Tennessee	Vermivora pergrina			x
Warbler, Wilson's	Wilsonia pusilla	x		
Waterthrush, Northern	Seiurus noveboracensis	x	x	
Widgeon, American	Mareca americana	x		
Woodpecker, Red-cockaded	Dendrocopos borealis	x		
Wren, House	Troglodytes aedon	x		
Wren, Long-billed Marsh	Telmatodytes palustris	x		
Wren, Short-billed Marsh	Cistothorus platensis	x		
Yellowlegs, Lesser	Totanus flavipes	x		

Bird Species Not In Mammoth Cave National Park But Within Study Area.

Common Loon. *Gavia immer*. Transient
Horned Grebe. *Podiceps auritus*. Transient
Common Egret. *Casmerodius albus*. Transient
Snowy Egret. *Leucophoyx thula*. Transient
Cattle Egret. *Bubulcus ibis*. Transient
Yellow-Crowned Night Heron. *Nyctanassa violacea*. Transient
Gadwall. *Anas strepera*. Transient
Greater Scaup. *Aythya marila*. Transient
Common Goldeneye. *Bucephala clangula*. Transient
Ruddy Duck. *Oxyura jamaicensis*. Transient
Hooded Merganser. *Lophodytes cucullatus*. Summer resident
Red-breasted Merganser. *Mergus serrator*. Transient
Peregrine Falcon. *Falco peregrinus*. Transient
Semipalmated Plover. *Charadrius semipalmatus*. Transient
American Golden Plover. *Pluvialis dominica*. Transient
Black-bellied Plover. *Squatarola squatarola*. Transient
Ruddy Turnstone. *Arenaria interpres*. Transient
Willet. *Catoptrophorus semipalmatus*. Transient
Greater Yellowlegs. *Totanus melanoleucus*. Transient
Pectoral Sandpiper. *Erolia melanotos*. Transient
Semipalmated Sandpiper. *Ereunetes pusillus*. Transient
Herring Gull. *Larus argentatus*. Transient
Ring-Billed Gull. *Larus delawarensis*. Transient
Bonaparte's Gull. *Larus philadelphia*. Transient
Common Tern. *Sterna hirundo*. Transient
Black Tern. *Chlidonias niger*. Transient
Barn Owl. *Tyto alba*. Rare Resident
Bobolink. *Dolichonyx oryzivorus*. Spring Migrant
Brewer's Blackbird. *Euphagus cyanocephalus*. Transient
Leconte's Sparrow. *Passerherbulus caudactus*. Transient
Henslow's Sparrow. *Passerherbulus henslowii*. Transient
Lincoln's Sparrow. *Melospiza lincolnii*. Transient
Lapland Longspur. *Calcarius lapponicus*. Rare Winter Resident

LAND SNAILS OF MAMMOTH CAVE NATIONAL PARK
(HUBRICHT, 1957)

1. Polygyra pustuloides (Bland)
2. *Polygyra leporina* (Gould)
3. *Stenotrema angellum* Hubricht
4. *Stenotrema barbatum* (Clapp)
5. *Stenotrema stenotrema* (Pfr.)
6. *Stenotrema hirsutum* (Say)
7. *Stenotrema fraternum* (Say)
8. *Mesodon thyroidus* (Say)
9. *Mesodon clausus* (Say)
10. *Mesodon zaletus* (Binn.)
11. *Mesodon elevatus* (Say)
12. *Mesodon appressus* (Say)
13. *Mesodon inflectus* (Say)
14. *Triodopsis vulgata* Pils.
15. *Triodopsis denotata* (Fer.)
16. *Triodopsis obstricta* (Say)
17. *Triodopsis albolabris* (Say)
18. *Allogona profunda* (Say)
19. *Haplotrema concavum* (Say)
20. *Euconulus chersinus* (Say)
21. *Guppya sterkii* (Dall)
22. *Retinella paucilirata* (Mor.)
23. *Retinella praecox* H.B. Baker
24. *Retinella wheatleyi* (Bland)
25. *Retinella lewisiana* (Clapp)
26. *Mesomphix vulgatus* H.B. Baker
27. *Mesomphix nuidus* Hubricht
28. *Mesophix friabilis* (W.G.B.)
29. *Paravitrea capsella* (Gould)
30. *Hawaiia minuscula* (Binn.)
31. *Ventridens gularis* (Say)
32. *Ventridens ligerus* (Say)
33. *Ventridens intertextus* (W.G.B.)
34. *Zonitoides arboreus* (Say)
35. *Zonitoides limatulus* (Binn.)
36. *Zonitoides lateumbilicatus* (Pils.)
37. *Striatura meridionalis* (P.& F.)
38. *Anguispira alternata* (Say)
39. *Discus patulus* (Desh.)
40. *Helicodiscus parallelus* (Say)
41. *Helicodiscus eiganmanni* Pils.
42. *Helicodiscus punctatellus* Morrison
43. *Punctum minutissimum* (Lea)
44. *Punctum blandianum* Pils.
45. *Punctum vitreum* H.B. Baker
46. *Punctum smithi* Morrison
47. *Deroceras laeve* (Mull.)
48. *Philomycus carolinianus* (Bosc)
49. *Pallifera mutabilis* Hubricht
50. *Pallifera marmorea* Pils.

51. *Pallifera secreta* (Ckll.)
52. *Succinea ovalis* (Say)
53. *Quickella vermeta* (Say)
54. *Strobilops labyrinthica* (Say)
55. *Strobilops aenea* Pils.
56. *Gastrocopta armifera* (Say)
57. *Gastrocopta clappi* (Sterki)
58. *Gastrocopta contracta* (Say)
59. *Gastrocopta tappaniana* (C.B. Adams)
60. *Gastrocopta pentodon* (Say)
61. *Gastrocopta corticaria* (Gould)
62. *Gastrocopta procera* (Gould)
63. *Pupoides albilabris* (C.B. Adams)
64. *Vertigo ovata* (Say)
65. *Columella edantula* (Drap.)
66. *Cionella lubrica morseana* Doherty
67. *Carychium exile* H.C. Lea
68. *Carychium etygium* Call
69. *Carychium costatum* Hubricht
70. *Carychium nannodes* Clapp
71. *Helicina orbiculata* (Say)
72. *Pomatiopsis cincinnatiensis* (Lea)
73. *Pomatiopsis lapidaria* (Say)
74. *Polygyra plicata* (Say)
75. *Triodonsis tridentata* (Say)

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PART B. MAN-MADE ENVIRONMENT

DEVELOPMENT OF PRESENT POPULATION ESTIMATES

Munfordville Estimation of Present Population

Number of Residences (1970) - 439
Population (1970) - 1,233
Persons/Residence = $\frac{1,233}{439}$ = 2.8 persons/residence

Approximate # of Water Connections in 1970 - 530
Persons/Water Connections = $\frac{1,233}{530}$ = 2.33 persons/water connection

Estimate of 1977 Population by Residences

New Housing Within City Limits

1975 - 10 houses
1976 - 7 houses
1977 - 5 houses
1978 - 7 houses
TOTAL - 29 houses

Average for years 1974-1978 is 7.25 houses/year. Assume this rate of construction for 1970-1978 or about 54 new houses constructed since 1970.

Extending the city limits north of the Interstate 65 interchange since 1970 has added about 30 more residences to the city's total.

An estimate of 1977 residences:

439 - 1970
54 - Estimated New Construction
30 - Annexation

523 - Total Estimated # of Residences in 1977

Assuming the number of persons per residence remains approximately constant, 1977 population estimate for Munfordville is as follows:

523 Residences x 2.8 $\frac{\text{persons}}{\text{residence}}$ = 1,464 People within Munfordville City Limits

Estimate of 1977 Population by Water Connection:

Total 1977 Water Connections - approximately 612

Estimate of Water Connections with City Limits:

612	
- 13	(Perryville Area)
599	
- 5	(New Houses near Munfordville Apts.)
594	
- 2	(Mundfordville Apts.)
592	

592 Connections x 2.33 Persons/Connection = 1,379

Estimate based on the average of the two methods.

$$\frac{1{,}379 + 1{,}464}{2} = 1{,}421.7$$

Estimate of present population with Mundfordville City Limits = 1,420

Population of Mundfordville "Area" is somewhat larger and should be considered since Munfordville provides water to areas outside the city limits.

Estimated Population Outside
Munfordville Limits with
Municipal Water Service

18 houses in Perryville x 2.8 persons/house

= 50 persons

5 new houses near Mundfordville Apartments @ 2.8 persons/house

= 14 persons

192 people living in Munfordville Apartments

Total = 256

Total Munfordville Area Estimated Population

256	Estimated Number of Persons Outside City Limits Served by Water
+ 1,420	Estimated Population Within the City Limits
1,676	

Cave City Estimation of Present Population

Assumptions:

1) Since before 1970, nearly the entire population within the corporate limits has been served by city water.
2) Number of persons per connection is approximately the same in 1977 as in 1970.
3) Number of persons per residential connection is approximately the same in 1977 as 1970.
4) Per capita domestic water consumption is approximately the same in 1977 as in 1970.

Estimation by persons/connection:

Approximately 585 connections in 1970
1,818 persons according to 1970 census

$$\frac{1{,}818}{585} = 3.1 \text{ persons/connection}$$

Approximately 714 connections in 1977

$$3.1\ \frac{\text{persons}}{\text{connection}} \times 714 \text{ connections} = 2{,}218 \text{ petsons (1977 Estimates)}$$

Estimation by persons/residential connection:

Approximately 482 Residential Connectives in 1970
1,818 persons according to 1970 census

$$\frac{1{,}818}{482} = 3.77 \text{ persons/residential connection}$$

Approximately 570 residential connections in 1977

3.7 persons/connection x 570 connections = 2,151 persons (1977 estimate)

Estimation by per capita domestic water consumption:

Approximate average residential water consumption in 1970 - 53,000 gpd
1,818 persons according to 1970 census

$$\frac{53{,}000 \text{ gpd}}{1{,}818 \text{ persons}} = 29.2 \text{ gpcd}$$

Average residential water consumption in 1977 - 68,647 gpd

68,647 gpd/29.2 gpcd = 2,350 persons (1977 Estimate)

Average these three methods:

2,350
2,151
2,218

6,719/3 = 2,239 or 2,250

Since per capita consumption may have increased over the years, the estimate by this method is probably least reliable. The 1977 population estimate is obtained by averaging the two approximations developed by persons/connection.

$$\frac{2{,}218 + 2{,}151}{2} = 2{,}184 \quad \text{or} \quad 2{,}180$$

Horse Cave Estimation of Present Population

Assumptions:

1) Since before 1970, nearly the entire population within the corporate limits has been served by city water.

2) Number of persons per connection is approximately the same in 1977 as in 1970.

3) Number of persons per residential connection is approximately the same in 1977 as 1970.

4) Per capita residential water consumption is approximately the same in 1977 as in 1970.

Estimation by persons/connection:

Approximately 716 connection in 1970
2,068 persons according to 1970 census

$$\frac{2,068}{716} = 2.9 \text{ persons/connection}$$

Approximately 824 connections in 1977

$$2.9 \frac{\text{persons}}{\text{connection}} \times 824 \text{ connections} = 2,389 \text{ persons (1977 Estimates)}$$

Estimation by persons/residential connection;

approximately 600 residential connections in 1970
2,068 persons according to 1970 census

$$\frac{2,068}{600} = 3.45 \text{ persons/residential connection}$$

approximately 712 residential connections in 1977

$$3.45 \text{ persons/connection} \times 712 \text{ connections} = 2,456 \text{ persons (1977 estimate)}$$

Estimation by per capita residential water consumption:

Approximate average residential water consumption in 1970 - 60,500 gpd
2,068 persons according to 1970 census

$$\frac{60,500 \text{ gpd}}{2,068 \text{ persons}} = 29.3 \text{ gpcd}$$

Average residential water consumption in 1977 - 75,818 gpd

75,818 gpd/29.3 gpcd = 2,588 persons (1977 estimate)

Average of the three methods:

2,588
2,456
2,389

7,433

7,433/3 = 2,477

The average per capita residential water consumption may have increased greater than expected since 2,588 is significantly higher than the 2,477 average. Using only the person/connection method, the estimated 1977 population is obtained by averaging the two approximations.

$$\frac{2,456 + 2,389}{2} = 2,422 = 2,420$$

Park City Estimation of Present Population

Assumptions:

1) Since before 1970 nearly the entire population within the city limits has been served by city water.

2) The number of persons per connections in 1977 is the same as in 1970.

3) Per capita consumption is approximately the same in 1977 as in 1970

Estimation by persons/connection;

Approximately 200 connections in 1970
567 persons according to 1970 census

567 persons/200 connections = 2.83 persons/connections

Approximately 225 connections in 1977

2.83 persons/connection x 225 connections - 636 persons
(1977 estimate)

Estimation by per capita consumption:

Average Park City water consumption in 1970 - 35,000 gpd
567 persons according to 1970 census

35,000 gpd/567 persons = 62 gpcd

Average Park City water consumption in 1977 - approximately 42,000 - 48,000 gpd

$$\frac{42{,}000 \text{ gpd}}{62 \text{ gpcd}} = 677 \text{ persons or } \frac{48{,}000 \text{ gpd}}{62 \text{ gpcd}} = 744 \text{ persons}$$

Since estimates of 1977 water consumption or demand are only approximate due to problems with the water system, assume persons/connection method is more accurate. Assume population is 640.

DEVELOPMENT OF POPULATION PROJECTIONS

Projecting Populations for 1980, 1990 and 2000

(a) Method for projecting populations for Horse Cave, Cave City, Munfordville (see Table AI-7).

  (1) Estimate 1977 population.

  (2) Determine KPDO population projection for 1977 by graphical interpolation (Figure AI-1).

  (3) Obtain difference of KPDO 1977 projection and 1977 population estimate.

  (4) Adjust 1980 KPDO population by adding the difference determined in step (3)

  (5) Obtain 1990 and 2000 adjusted projections by increasing the 1980 projection in step (4) by percentage increases predicted by KPDO projections.

(b) Method for projecting Park City

  (1) Estimate 1977 population by approximate # of water connections.

  (2) Assume 1977 to be actual population and use the 7 year increase as the basis for geometric growth. (see Table AI-7).

TABLE AI-7 POPULATION PROJECTIONS FOR PERMANENT RESIDENTS

Kentucky Program Development Office Projections

	(1) (Census) 1970	(2) 1975	(3) By graphical interpolation 1977	(4) 1980	(5) 1990	(6) (>1980)	(7) 2000	(8) (>1990)
Cave City	1,818	1,955	1,990	2,015	2,230	.107	2,470	.107
Horse Cave	2,068	2,114	2,200	2,362	2,712	.15	3,093	.14
Munfordville	1,233	1,280	1,300	1,342	1,473	.098	1,614	.096
Park City	576	592	600	628	672		723	

GFC&C Projections and Calculations

	(9) Estimated 1977	(10) 1980 {(4)+ (9)-(3)}	(11) 1990 {(10)+(10)(7)}	(12) 2000 {(11)+(11)(8)}
Cave City	2,180	2,207	2,440	2,700
Horse Cave	2,420	2,580	2,960	3,380
Munfordville (Area)	1,680	1,700	1,860	2,040
Park City	640			
by geometric series		600	750	850

$$\log y_m = \log y_1 + (\log y_1 - \log y_e)\,(t_m - t_1)/(t_1 - t_e)$$

y_m = desired year population (1980, 1990, 2000)
y_1 = 1977 population estimate
y_e = 1970 census
t_1 = year of 1977
t_e = year of 1970
t_m = desired year 1980, 1990 or 2000

GRAPHICAL REPRESENTATION OF POPULATION ESTIMATES AND PROJECTIONS

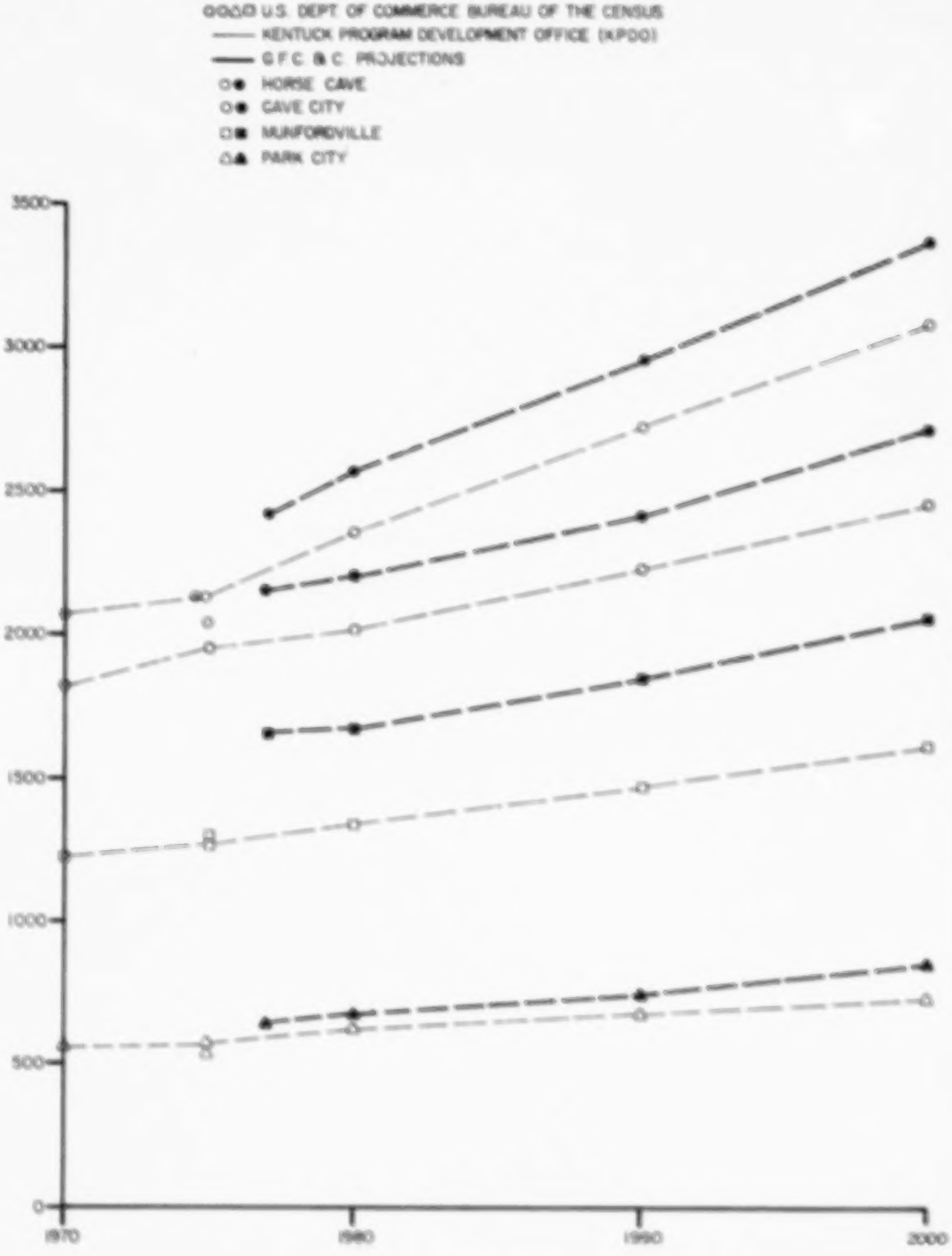

FIGURE A I-1

ESTIMATION OF WASTEWATER FLOWS AS A PERCENTAGE OF WATER CONSUMPTION

Estimation of Wastewater Flows as a Percentage of Water Consumption

TABLE I - 8

CAVE CITY WATER CONSUMPTION/WASTEWATER DATA FOR 8 MONTHS IN 1977

Month	Water Consumption (gpd)	Water Consumption of Sewer Customers (gpd)	Wastewater Flow (gpd)	% Wastewater Flow
April	226,130	203,517	189,000	93
May	194,000	174,600	174,000	100
June	261,113	235,002	203,000	86
July	270,777	243,699	252,000	104
August	326,612	293,950	252,000	86
September	281,680	253,512	211,000	83
November	215,000	193,500	128,000	66
December	209,719	188,747	163,000	86

*(90% of water consumption) based on the number of water and sewer connections, about 90% of the water customers are served by the Cave City sewerage system.

Average wastewater flow equals approximately 87% of water consumption based on the above data.

WATER CONSUMPTION DATA

Horse Cave Water Consumption Data*

1977 Average Daily Water Consumption ≅ .359 mgd

Average Daily Residential Consumption ≅ 0.076 mgd

Average Daily Industrial Water Consumption ≅ 0.222 mgd

Average Daily Commercial Water Consumption ≅ 0.061 mgd

These data are obtained from records of metered water consumption from 1970-1977. They reflect consideration of actual 1977 metered consumption as well as graphical interpretation of recent trends (Figure **AI-2**).

(1) Estimated Residential Per Capita Consumption

$$\frac{76{,}000 \text{ gpd}}{2{,}420 \text{ 1977 Population Estimate}} \cong 31.4 \text{ gpcd}$$

(2) Average Residential Consumption Per Residential Water Connection

$$\frac{76{,}000 \text{ gpd}}{712 \text{ 1977 Residential Connections}} = 107 \text{ gpd/Residential Connections}$$

(3) Average Commercial Consumption Not Associated With Tourism Per Non-Motel Commercial Water Connections

380 gpd/Non-Motel Commercial Connection (Appendix I)

(4) Average Daily Commercial Consumption Associated With Tourism/Motel Unit

160 gpd/Motel Unit

(5) Peak Seasonal Average Daily Commercial Consumption Associated With Tourism/Motel Unit

265 gpd/Motel Unit (see Cave City)

Because there are relatively few tourist accommodations in Horse Cave, seasonal commercial consumption is not detected. This number (265 gpd/motel unit) is considered applicable to Horse Cave, however.)

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*Based on Green River Valley Water District billing records.

HORSE CAVE WATER CONSUMPTION DATA FROM WATER BILLING RECORDS

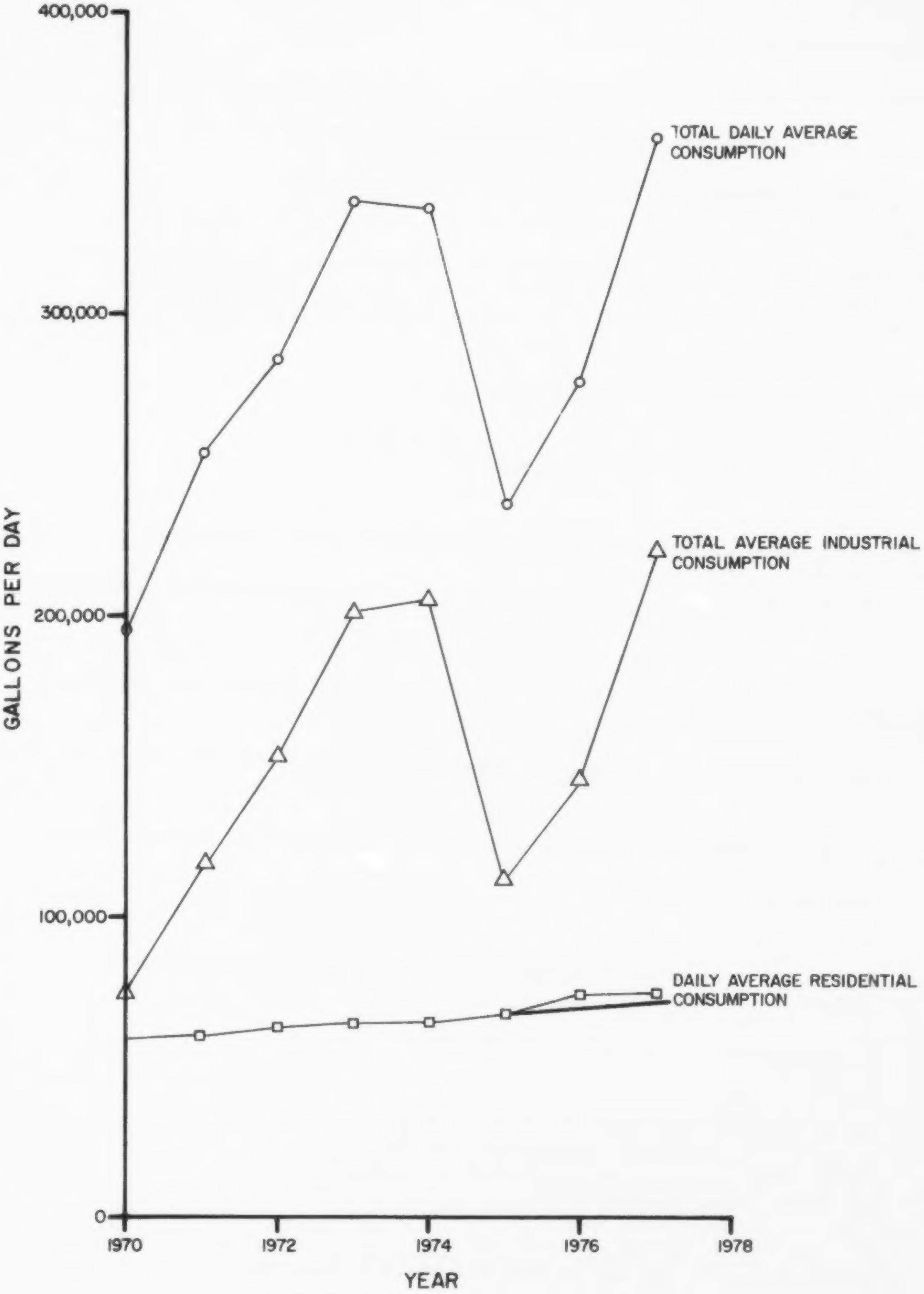

FIGURE A I-

(6) Peak Seasonal Average Daily Residential Consumption Factor

Average for 1975-1977 = 1.16

(7) Number of Non-Motel Commercial Connections Per Capita

103 non-motel connections/2,420 1977 population estimate = .042 connections/persons

Cave City Water Consumption Data*

1977 Average Daily Consumption ≅ 0.235 mgd

Average Daily Residential Consumption ≅ 0.068 mgd

Average Daily Commercial Consumption ≅ 0.167 mgd

These data are obtained from metered water consumption records for 1970-1977. They reflect consideration of actual 1977 consumption as well as graphical interpretation of recent trends (Figure AI - 3).

(1) Estimated Residential Per Capita Consumption (1977)

$$\frac{68{,}000 \text{ gpd}}{2{,}180 \quad \text{1977 Population Estimate}} = 31.2 \text{ gpcd}$$

(2) Average Residential Consumption Per Residential Water Connection

$$\frac{68{,}000 \text{ gpd}}{572 \quad \text{1977 Residential Connections}} = 119 \text{ gpd/Residential Connections}$$

(3) Average Commercial Consumption Not Associated With Tourism Per Non-Motel Commercial Water Connections

382 gpd/Non-Motel Commercial Connection (Appendix I).

(4) Average Daily Commercial Consumption Associated With Tourism/Motel Unit

160 gpd/Motel Unit (Appendix I)

(5) Peak Seasonal Average Daily Commercial Consumption Associated With Tourism/Motel Unit

During the past 4 years peak seasonal commercial consumption averaged about 1.44 times the daily average commercial consumption. For Cave City in 1977, this represents an additional consumption of 73,490 gpd (.44 x 167,000 gpd) or 105 gpd/motel unit (73,490 gpd/motel unit).

During Peak Tourist Season Average Daily Commercial Consumption ≅ 265 gpd/motel unit

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*Based on Green River Valley Water District billing records.

CAVE CITY WATER CONSUMPTION DATA FROM WATER BILLING RECORDS

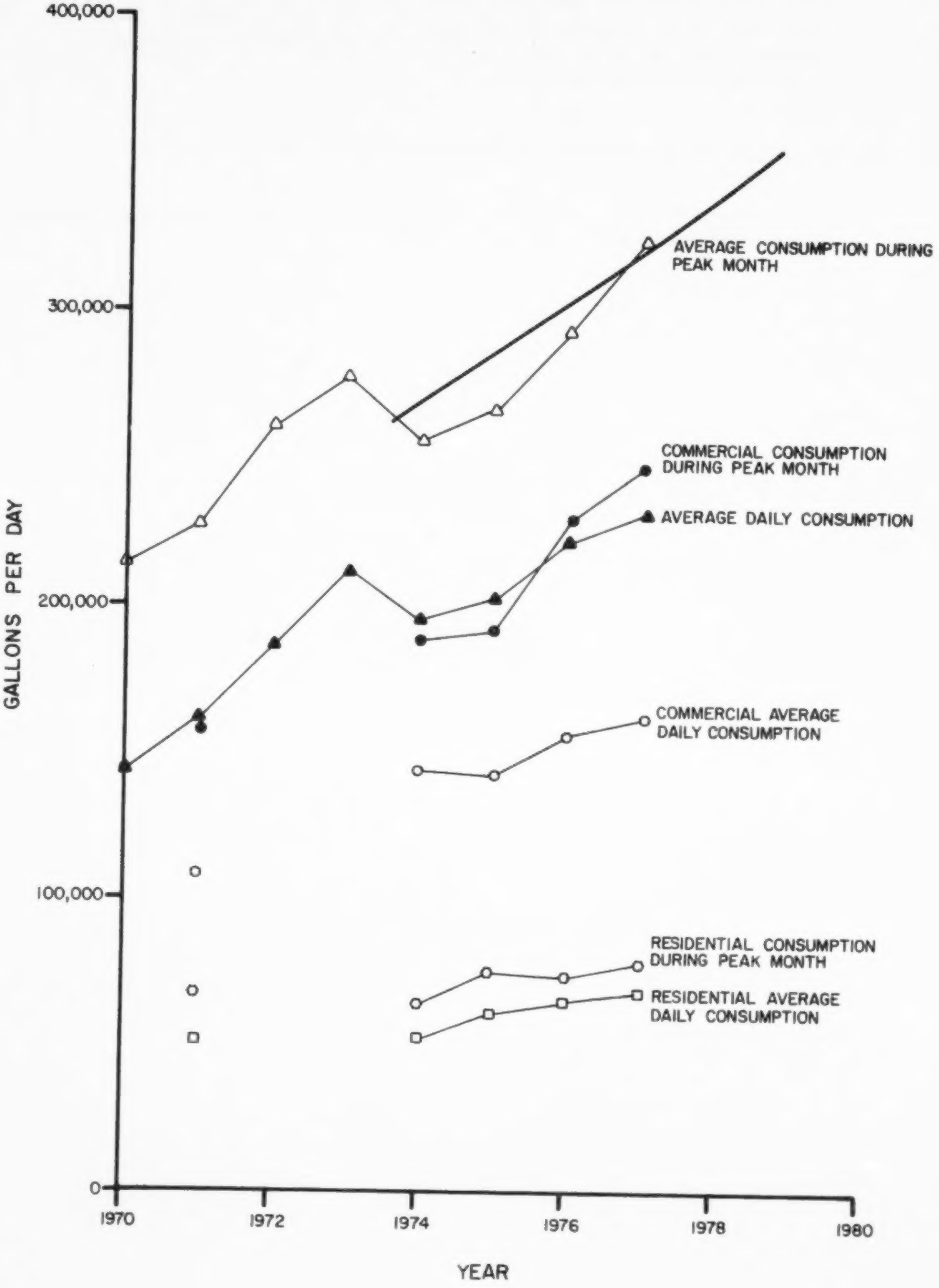

FIGURE A I-3

(6) Peak Seasonal Average Daily Residential Consumption Factor

Data from 1970-1977 indicate that the residential water consumption is highest during August, the peak tourist season. During this time residential consumption is about 1.15 times the average.

(7) Number of Non-Motel Commercial Connections Per Capita

129 non-motel water connections / 2,180 1977 population estimate = .059 connections/person

Munfordville Water Consumption Data

Average Daily Pumpage = 150,000 gpd
(1976-1977 as Reported by Kentucky Division of Water Quality)

This appears high based on population projections and past pumping rates.

Estimation of Residential Consumption:

Because Munfordville is a different type of community than Horse Cave or Cave City, it is expected that residential per capita water consumption may vary. There is little data available for Munfordville, but this limited data indicate Munfordville per capita residential consumption may be significantly greater than the other towns.

January - May 1978 Average Consumption at = *9,797 gpd
Munfordville Apartments

192 Residents This represents $\frac{9,797}{192}$ gpd = 51 gpcd

September-October 1977 Munfordville Residential Consumption = *64,270 gpd

Estimated 1488 population served, this represents $\frac{64,270}{1488}$ = 43 gpcd
(1680 Total Population - 192 in Apartments)

Munfordville Apartment residents, per capita consumption may be slightly higher than average, and missing billings for September and October may tend to raise the 43 gpcd figure. Assume 45 gpcd.

Number of Commercial connections Per Capita = 69/1680 =
0.41 Commercial Connections/Capita

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*Based on actual billings.

WATER CONSUMPTION PROJECTIONS

Cave City - Water Consumption Projections

Assumptions:

(1) Residential per Capita demand - Residential per Capita consumption increased from 29.2 gpcd to an estimated 31.2 from 1970-1977, an increase of about .28 gpd/year. This is anticipated because of younger people and newer housing in the area. However, effects at water conservation should decrease this increasing demand rate. It is assumed that increasing demand will be as follows:

1977-1980	.28 pgd/year
1980-1990	.2 gpd/year
1990-2000	.1 gpd/year

(2) The number of non-motel commercial connections per capita remains the same during the entire study period.

(3) Because Cave City already has supporting facilities, it is assumed that at least half of the 400 anticipated new motel units in the area (Appendix II) will be constructed in Cave City. For planning purposes, 100 additional units are projected during 1980-1990 and 100 between 1990 and 2000.

(4) The average water consumption associated with commercial connections, 160 gpd/motel unit and 380 gpd/non-motel commercial connection, remains constant.

(5) The average water consumption associated with motel units during peak months is 265 gpd/motel unit.

Estimated Average Consumption= Residential Average Consumption

+ Non-Motel Commercial Average Consumption
+ Motel Average Consumption
+ Trailer Park Consumption (55 mobile homes)

Where: Residential = (Population projection) X (Estimated Per Capita Consumption)

Non-Motel Commercial= (Population projection) X (Non-Motel Commercial Per Capita) X 380 gpd/non-motel commercial connection

Motel Average = (Projected # of motel units) x (150 gpd/motel unit)

Trailer Park = 6,545 gpd

Estimated Average Consumption= 1.15 (Residential Average) During Peak Months

+ Non-Motel Commercial Average
+ Motel Average Consumption During Peak Months

Where: Motel Average During Peak Months = 265 gpd/motel unit X # of motel units

Cave City Projections

	Trailer Park(gal).	Residential Average (gal)	Non-Motel Commercial Avg.(gal)	Motel Average (gal)	Total Avg. Consumption (gal)	1.15xResidential Average (gal)	Motel Avg.During Peak Month (gal)	Total Avg. Consumption During Peak Month (gal)
1980	6,545	70,712	50,000	111,680	239,000	81,318	184,970	323,000
1990	6,545	81,000	55,000	127,680	270,000	93,150	211,470	366,000
2000	6,545	94,600	61,000	143,680	306,000	108,790	237,970	414,000

Horse Cave - Water Consumption Projections

Assumptions:

(1) Residential per Capita demand - Residential per capita consumption increased from about 29.2 gpcd in 1970 to 31.4 gpcd in 1977, an increase of about 0.31 gpcd/year. Efforts at water conservation should decrease this increasing demand rate. It is assumed that increasing demand will be as follows:

		gpcd
1977-1980	.31 gpcd/year	32.3-1980
1980-1990	. 2 gpcd/year	34.3-1990
1990-2000	. 1 gpcd/year	35.3-2000

(2) The number of non-motel commercial connections per capita remains constant during the study period. (0.42)

(3) One hundred (100) additional motel units will be constructed by the year 2000. Assume 50 constructed during 1980-1990 and 50 from 1990-2000.

(4) The average water consumption associated with commercial connections, 160 gpd/motel unit and 380 gpd/non-motel commercial connection, remains constant during the study period.

(5) The average water consumption associated with motel units during the peak month is 265 gpd/motel unit.

(6) Industries in Horse Cave will expand 10% by the year 2000. Assume +5% from 1980 to 1990 and +5% from 1990-2000. However, Ken Dec Inc. plans to reduce process wastewaters by 40% in the future. This represents a decrease of 30%, given the assumed 10% expansion, 15% from 1980-1990 and 15% from 1990-2000.

(7) Assume industrial water consumption = 1977 maximum month average consumption.
= 235,000 gpd (Ken dec Inc.) +
37,000 gpd (Hart Co. Cremeries)

Estimated Average Consumption = Residential Average Consumption
+ Non-Motel Commercial Average Consumption
+ Motel Average Consumption
+ Industrial Consumption

Where: Residential Average = (Population Projection) X (Estimated per Capita Consumption)

Non-Motel Commercial = (Population Projection) X (# of non-motel commercial per Capita) X 380 gpd/non-motel commercial connection

Motel Average = (Projected # of X (160 gpd/motel unit)
Motel Units)

Estimated Average Consumption
During Peak Months = 1.16 (Residential Average)

+ Non-Motel Commercial Average Consumption
+ (Projected # of X 265 gpd/motel unit
Motel units)
+ Industrial Consumption

Horse Cave Projections

	Residential Average (gpd)	Non-Motel Commercial Avg.(gal)	Motel Average (gpd)	Total Avg. Consumption (gpd)	1.15xResidential Average (gpd)	Motel Avg.During Peak Month (gpd)	*Industrial Consumption (gpd)	Total Avg. Consumption During Peak Month (gpd)
1980	83,334	41,177	22,720	419,000	96,667	37,630	272,000	447,000
1990	101,528	47,241	30,720	418,089	117,772	50,880	238,600	454,493
2000	119,314	53,944	38,720	417,178	138,404	64,130	205,200	461,678

* Industrial Projections:

	Kendec, Inc.	Hart Co. Creameries	Total
1980	235,000	37,000	272,000
1990	199,750	38,850	238,600
2000	164,500	40,700	205,200

Park City - Water Consumption Projections*

Assumptions:

(1) Water consumption is similar to Cave City and Horse Cave for the following:

a. Per capita residential consumption

a. Per capita residential consumption	1980	32.3 gpcd
	1990	34.3 gpcd
	2000	35.3 gpcd

b. Water consumption per motel unit for average and peak month (160 gpd and 265 gpd)

c. Water consumption for non-motel commercial connection (380 gpd)

(This assumption is required since Park City consumption records are unavailable and leaks in system make pumpage records useless)

(2) The number of non-motel commercial connections as more tourist associated businesses locate in Park City

1980	.036	non-residential connection per capita (present rate)
1990	.039	
2000	.042	

(3) Of the projected 400 Motel unites to be constructed in the area, one hundred will be constructed in Park City, 50 from 1980-1990 and 50 from 1990-2000.

*For Methodology see Horse Cave or Cavy City Water Consumption Projections.

Park City Projections

	Residential Average (gpd)	Non-Motel Commercial Avg. (gpd)	Total Average (gpd)	Total Avg. Consumption (gpd)	1.15xResidential Average (gpd)	Motel Avg.During Peak Season (gpd)	Total Avg.Consumption During Peak Season (gpd)
1980	21,318	9,028	6,720	37,066	24,516	11,130	44,674
1990	25,725	11,115	14,720	51,560	29,584	24,380	65,079
2000	30,005	13,566	22,720	66,291	34,505	37,630	85,701

Munfordville - Water Consumption Projections

Assumptions:

(1) Residential Consumption = 45 gpcd 1980 and increases .1% per year afterward; 1990 = 45.45 gpcd, 2000=45.9 gpcd.

(2) The # of commercial connections per capita (.041) remains constant during the planning period.

(3) The commercial water consumption per residential connection is 380 gpd, the same as that estimated for Horse Cave and Cave City non-tourist commercial.

(4) There is no significant seasonal variation in demand due to tourist influence.

Average Daily Consumption = Average Daily Residential + Average Daily Commercial Consumption

Average Daily Residential Consumption = (gpcd) X (Population Projection)

Average Daily Commercial Consumption = (380 gpd/commercial customer) X (# of Commercial Connections)

Maximum Daily Consumption = 1.4 X Average Daily Consumption

For Munfordville Projections

	Average Daily Residential Consumption	Average Daily Commercial Consumption	Total Average Consumption	Maximum Daily Consumption
1980	76,500	26,532	103,032	144,244
1990	84,537	29,029	113,566	158,992
2000	93,636	31,838	125,474	175,664

ESTIMATION OF YEAR 2000 MOTEL UNITS AND AN ESTIMATION OF TOURIST RELATED AND NON-TOURIST RELATED COMMERCIAL WATER-CONSUMPTION

Year 2000 Motel Unit Estimates

Estimating the number of motel units in the municipalities of Horse Cave, Cave City and Park City in the year 2000 is based on two assumptions:

(1) The present number of motel units in the municipalities is optimum for the present level of cave visitation during the peak tourist season.

(2) The number of motel units in the three municipalities will increase in proportion to average daily cave visitation during the peak month of the tourist season.

Presently, there are 870 motel units in the three towns, 698 in Cave City; 130 in Horse Cave and 42 in Park City. During the past seven years cave visitation has remained constant at an average of about 5,100 people per day during peak months. The latest estimates, developed by William E. Pollard consultants as part of a transportation study being prepared for the Park, indicate cave visitation to increase to an average 7,100 - 7,800 visits/day during the peak tourist season in year 2000. Using 7,450 visits/day as the year 2000 estimate, this corresponds to about a 46% increase over present visitations.

Estimated # of motel units year 2000

1.46	x	870	=	1270
46% increased cave visitation		present # of motel units		Estimated # of motel units year 2000

Therefore, the number of additional rooms is about 400. Today, occupancy of the rooms is about 90% during the peak season. If a 95% occupancy is assumed for year 2000, however, the estimated number of rooms is about 1,204, an increase of about 330 rooms. The number of rooms constructed is expected to fall in the range of 300-400.

Estimation of Tourist Related and Non-Tourist Related Commercial Water Comsumption

1977 Average Commercial Consumption in Cave City = 0.165 gpd
1977 Average Commercial Consumption in Horse Cave = 0.062 gpd
Motel Units in Cave City = 698
Motel Units in Horse Cave = 142

Assumption: Water consumption associated with tourism can be correlated with motel units and should be similar for Horse Cave and Cave City.

Therefore: If x = average daily commercial consumption associated with tourism (gpd/motel unit)

y = average daily commercial consumption not associated with tourism (gpd/non-motel commercial water connection)

Then: $142x + 103y = 62{,}000$ gpd
$698x + 129y = 160{,}455$ gpd

Where: 142 = # motel units in Horse Cave
698 = # motel units in Cave City
103 = # non-motel connections in Horse Cave (107 commercial - 4 motel = 103)
129 = # of non-motel connections in Cave City

145 commercial connections
-14 motel connections
-2 trailer park connections
129 non-motel connections

62,000 gpd = average daily commercial consumption in Horse Cave
160,455 gpd = average daily commercial consumption in Cave City
(167,000 gpd - *6,545 gpd from 55 mobile homes = 160,455 gpd)

*Two commercial trailer parks have 55 mobile homes. It is estimated that consumption for each residential connection is about 119 gpd. Therefore 55 x 119 gpd/residence = 6,545.

Solving for x and y

x = average daily commercial consumption = 159 gpd/motel unit associated with tourism/motel unit

y = average daily commercial consumption = 382 gpd/non-motel commercial connection not associated with tourism/commercial connection

For Projection Purposes

x = 160 gpd/motel units
y = 380 gpd/non-motel commercial connection

MAMMOTH CAVE NATIONAL PARK WATER CONSUMPTION

Water Demand in National Park

Consumption Data Available for Mammoth Cave National Park from Park Master Plan.

August 1970

Great Onyx Civilian Conservation Center	1,308,930 gal.
National Park Concessions, Inc. (Hotels, Restaurant Camper's Store Etc.)	1,187,560 gal.
National Park Service (Visitor Center, Picnic Area, Campground, Employee Residences)	2,796,690 gal.
Total	5,293,180 gal.

August 1970 represents a peak month of park visitation, an estimated 326,550, which is exceeded only by July 1977 visitation of approximately 345,000.

During August 1970 Cave Visitation $= \frac{159,031}{31 \text{ days}} = 5,130$ cave visits/day

Park Visitation $= \frac{326,550}{31 \text{ days}} = 10,534$ park visits/day

Because the Master Plan recommendations call for abandoning the Great Onyx Job Corps Center, water consumption at this facility will not be considered.

Projections: Calculations and Assumptions

August 1970 Average Daily Consumption at National Park Services, Inc.
Assume 20% losses in water system

1,187,560 gal/31 days = 38,308 x .8 (for water losses) = 30,646

Estimated Peak Day During August of 1970

1.5 x 30,646 = 45,969

Assumption: During peak days of August 1970 the facilities of the Concessioner were receiving maximum usage. Therefore, this demand remains constant throughout the study period since no new facilities are planned.

However, average daily demand during peak months is expected to increase to 1.25 times the 1970 average, 1.125 by 1990 and 1.25 by 2000.

Calculation of Consumption by Present Visitors Center.

August 1970 Average Day for
National Park Services = 2,796,690 gal/31 days = 90,215 gpd
(Visitor Center, Campground,
Picnic Area and Residences of Employees)

Assumption: The water system is well maintained and experiences only about 20% losses.

Therefore, daily consumption ≅ 72,172 gpd

Assumptions: 45 gallons/campsite/day = campground consumption rate

3 residents per employee residence
40 gpcd for employee residents

Picnic area water consumption is negligible

Estimated Campground Water Consumption:

45 gal/campsite/day x 145 campsites = 6,525 gpd

Assumption: Campground facilities do not increase with increasing visitation. Assume maximum day consumption is constant throughout the study period. However, average consumption increases by 1.125 in 1990 and 1.25 in 2000.

Estimated Residential Area Consumption:

18 residents x 3 persons/residence x 40 gpcd = 2,160 gpcd

Estimated Vistor Center Demand:

72,172 gpd	-	6,525 gpd	-	2,160 gpd	= 63,487 gpd
Total National Park Service		Campground		Residential Area	

Estimated Per Capita Consumption at Visitors Center =

63,487 gpd/10,534 park visits ≅ 6 gpd/park visitor

Assumption: Per visitor consumption is 6 gpd at the new staging area.

Water Consumption Projections:

Staging Area Consumption = (Projected # of Park Visitors) x 6 gpd/visitor

Staging Area Maximum Day Consumption = 1.5 x (Average Day)

Residential Area = 2,160 gpd average day
= 3,000 gpd maximum day

National Park Concessions
Maximum Day = 45,969 gpd

(August 1990 Average Day) = 1.125 x (August 1970 Average Day)
(August 2000 Average Day) = 1.25 x (August 1970 Average Day)

Total National Park Consumption = Park Concessions
+ Campground
+ Residential Area
+ Visitor Center

}National Park Services